

**HANDBOOK OF
CHEMICAL CONSERVATION
OF MUSEUM OBJECTS**



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DEPARTMENT OF MUSEOLOGY
Maharaja Sayajirao University of Baroda

HANDBOOK OF CHEMICAL CONSERVATION OF MUSEUM OBJECTS

By

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DEPARTMENT OF MUSEOLOGY
Maharaja Sayajirao University of Baroda



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FOREWORD

Shri V. L. Devkar, Director of Museum and Picture Gallery, Baroda, and the Head of the Museology Department of the M. S. University of Baroda, has asked me to write a foreword to this little brochure on "Chemical Conservation of Museum Objects". It gives me very great pleasure to do so.

The study of Museology in this country is neglected and there are very few Universities, which have provision for such training. In the M. S. University of Baroda we have a two years post-graduate diploma course in Museology. The University of Baroda from time to time invites eminent Museologists to supplement the lectures and teaching work done by the permanent members of the University staff of Museology.

This handbook on "Chemical Conservation of Museum Objects" is the result of some of the lectures given by Shri T. R. Gairola, Chemist, National Museum of India, New Delhi.

This is the first publication of the Museology Department, and it is hoped that there would be many more publications in future covering all the important fields of study in Museology. It is hardly necessary for me to emphasise the importance of proper preservation of objects in our Museums. The climate of our country is not very kind to them.

Apart from the students of Museology for whom this handbook is primarily intended, I am sure it will be useful to the Curators of Museums. Shri Gairola has rendered great service to the students of Museology for which he deserves our congratulation.

Baroda,
19th November, 1959.

J. M. MEHTA,
Vice-Chancellor,
Maharaja Sayajirao
University of Baroda.



PREFACE

The present "Handbook of Chemical Conservation of Museum objects," by Shri T. R. Gairola, Chemist, National Museum of India, New Delhi, is the first of a series of books and booklets to be published by the Department of Museology of the M. S. University of Baroda to meet the special needs of the Post-graduate students. Every year the University invites museum experts from different parts of the country and they cover a relevant portion of the course according to their specialised field of study. The lectures delivered by these experts when properly revised and illustrated form the basis of our publication series.

The preservation of antiquities forms an important portion of the Post-graduate Museology course offered by the M. S. University of Baroda. Shri T. R. Gairola has made a successful attempt to brief out the prescribed portion in concise and practical terms in his seven lectures arranged by the university for the students of Museology. He has divided the book into two parts. Part I deals with the cleaning and preservation of Organic materials and Part II deals with the treatment of metals and siliceous materials. In these two parts he has described in a lucid manner the fundamentals of museum laboratory techniques in so far as they relate to the preservation of a variety of Museum exhibits.

Although this book has been written for the Museology students, it will be found useful by Curators of the Indian Museums, Departments of Archaeology and Anthropology and all those who are generally interested in the preservation of works of art and antiquities.

I am very grateful to the University authorities and particularly to their Council of Scientific Research and Publication for according their kind permission to publish this book.

V. L. DEVKAR,
Director,
Museum and Picture Gallery,
and
Head, Department of Museology,
M. S. University of Baroda.

Baroda,

Dated 15th November, 1959.



INTRODUCTION

The excavations at Olympia, which began in 1875, were probably the first to be conducted on what are now considered to be the correct scientific principles and adequate scientific results of the excavations are rare before this date. But long before this date, some chemists had become interested in the composition of ancient materials and had obtained, independent of archaeological considerations, information that is still useful today in the field of chemistry connected with antique objects.

The science of preservation deals with (i) scientific investigations carried out to throw light on the composition and manufacture of the different material present in the museum, (ii) the determination of the causes of deterioration and formation of undesirable incrustation on the surface and the core which get defaced and the details of which get obliterated, (iii) the elimination of factors which cause deterioration and then the removal of undesirable incrustations and extraneous deposit from the object, (iv) chemically cleaning it in order to reveal the evidence of value to students and research scholars, (v) rendering it immune from further attack, (vi) and making it suitable for exhibition in the museum under possible ideal conditions so as to ensure its stability whether in storage or on exhibition.

The subject matter is necessarily very varied, based on day-to-day problems relating to metals, stones, terracottas, coins, textiles, manuscripts, paintings, books, prints, drawings and specimen of all kinds. It has to be borne in mind that each specimen that is submitted for treatment presents its own individual problems and very often new methods have to be devised to achieve satisfactory preservation and restoration. In common with the museums are the problems of the preservation of a picture gallery, where restoration and preservation of oil paintings and easel paintings need special treatment.

The objects in the museum belong to four categories according to their nature—(i) organic material, (ii) inorganic material, (iii) siliceous material, (iv) paintings such as oil paintings, easel paintings and wall paintings. Before an attempt is made for the preservation of any of the objects of the above classes, it is necessary to know the nature of the material which is required to be tackled. For this, a thorough scientific examination with the aid of chemical knowledge, microscopic, ultra violet, infra-red and X-ray equipment is necessary. Before preservation is attempted it is necessary that the causes of deterioration of the material are first investigated. It is only then that the proper methods of preservation can be devised. Experience and manipulative skill are the two most important factors which go a long way to affect preservation successfully.

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PART I

THE CLEANING AND PRESERVATION OF ORGANIC MATERIAL

General :—

Organic material in the Museum consists of textiles, (fabric-cotton and woollen) paper, birch-bark leather, ivory, horn, bone, cordage, basket-work, reed, straw matting, feather, hair, etc. Let us at the first instance discuss what actually is meant by the cleaning and preservation of this stuff and how the importance and urgency of this work arises. Organic material being of delicate nature is more susceptible to get disintegrated and destroyed by the agencies of decay than the material of metallic and siliceous nature when stored or exhibited under similar conditions. Even ageing effect is more pronounced in this material than in others. The maintenance of this collection in a sound condition involves their protection against a variety of causes which affect their appearance or even bring about their complete disintegration. The common agents responsible for deterioration are (1) atmospheric gases and impurities, (2) humidity and temperature, (3) bacteria, moulds and fungi, (4) insects and birds, (5) soluble salts and (6) light. Of these, perhaps the most destructive are insects amongst which clothes moths, book lice, silverfish,

carpet beetles and wood borers are familiar to the museums curator. If these forces, causing destruction, are not properly controlled, and checked, the result is complete destruction of the material.

By cleaning is meant the removal of all extraneous matter that has accumulated on the specimen by contact or contamination with foreign incrustation or stains and disfigurement appearing as a result of changes brought about by the agencies mentioned above. The effect of the former can be eradicated to a greater extent, and that of the latter can be minimised as far as possible. It is always found desirable to underdo cleaning than to overdo it, as otherwise the purpose for which cleaning is done gets defeated—either the object gets disintegrated or its antique character is lost. Suppose for example on a textile piece there is a white lime incrustation which is so obstinate that it requires hydrochloric acid for its removal, now if the acid has been used of a higher concentration than required and for a longer time, the fabric will get destroyed, but if the treatment is slightly underdone no such risk is involved and the incrustation is almost removed. During cleaning, tried chemical reagents are employed to remove the stains and deposits for just as long a time as they are necessary and when these have served the purpose, they are to be washed off completely as some of them prove harmful to the texture of the material if left unwashed. As a general rule, cleaning with aqueous solvents is carried out before fixation and consolida-

tion of the object is undertaken, but there are cases when this order of treatment is reversed.

The causes of deterioration have to be examined before preservative methods can be evolved, as each type of deterioration requires to be tackled in specific ways. Some of these causes are common but a few are widely different and so no common methods for preservation, as a whole, can be advocated. As a matter of fact each object of each class is treated in its own way, in order to make the cleaning and preservation effective. The first step towards preservation is to carry out regular inspections of exhibits so that any evidence of deterioration can be quickly noticed and dealt with promptly, also it is necessary to maintain the favourable humidity 40-60% and temperature 50°-75°F. conditions in the rooms where these articles are stored.

We may now discuss briefly how the agents of decay are responsible in bringing about the deterioration of different classes of this material. The condition of the atmosphere with regard to its contamination with harmful sulphuric acid from burning of coal in industrial towns, carbon-di-oxide, moisture and high temperature play havoc with organic material. The acids eat away the material, and moisture brings about favourable conditions for the growth of bacteria and fungi and makes some of the insects more active. The wide changes of humidity cause contraction and expansion in the fibres of the

material which ultimately succumb to these physical forces and get powdery. The problem gets complicated by the fact that some materials can be preserved quite well in a damp atmosphere, whilst others require dry conditions. Also when hygroscopic salts are present, the high and low humidity conditions bring about efflorescence and deliquescence of the salts which add to the disintegrating forces. Dust is injurious in so far as it entails frequent handling of the object for cleaning. Textiles, leather and paper get brittle in high temperatures. Light affects the pigments of coloured material and render textile fabric, paper and wood discoloured and tender. A knowledge of the composition and the mode of manufacture of the material is helpful in understanding the causes and effects of the forces of decay and thus evolving suitable methods for their preservation.

Before describing in detail the preservative methods adopted for each type of antiquities, it would be desirable if the various terms employed in preservation are explained so that only a passing reference of these will be enough later on. The terms are fumigation, sterilization, elimination of salts, strengthening, consolidation, repairing, mounting, backing, fixative, adhesive, preservative coating, restoration and renewing.

Fumigation and Sterilization

During the last few years a rapid advancement has been made in the development of the Chemistry

of fumigants, repellents and insecticides, which has put in the market a number of new chemicals with greater efficacy and utility. These are likely to alter the long established methods and processes. Time and careful research on the part of workers will enable us to introduce them in the field of museum science. It is found that none of these chemicals is a cure—all, but that each will find a useful place along with the older established materials. Science has thus placed at our disposal a wider variety of weapons to fight the insect, worm and fungal menace. Only a few of the fumigants and insecticides can be advocated for use in museums. They should be non-staining and should not in any way affect the texture of the specimen and the pigments in painted materials.

Fumigation :—

It is a process, used for destroying the insects, worm, moths or the like species by making use of suitable chemicals which volatilize and produce insecticidal fumes. A large number of fumigants have been tried and experimented upon and the safest is carbon-di-sulphide which can be used even in the case of painted panels with the precaution that naked light is to be avoided when it is being used, otherwise explosion and fire may take place. Other suitable chemicals used are naphthalene, benzine, petrol, formaldehyde, camphor, thymol, carbon-tetra-chloride, ethylene-di-chloride, hydrocyanic acid, para-di-chloro-benzene singly or in mixtures with pleasant smelling

liquids which conceal the unpleasant odour of the effective ingredient. Vacuum fumigation and hydrocyanic acid fumigation are most drastic. On principle no chlorocompound should ever be used with delicate or valuable objects. Fumigation is generally carried out in closed air tight boxes or drums, if the objects are small. But in the case of large sized objects, with deep insect holes, the holes are injected with the fumigating liquids and plugged with stoppers but this is a lengthy process. Spraying gives only a superficial treatment. There are a very large number of commercial fumigants in the market but for use with antiques, the choice is limited to only a few. Thymol fumigation has been found very effective when specimen are affected with fungus and mildew. The period of exposure of the object to fumigant is an important factor for its efficacy.

Sterilization (Fungicidal and Insecticidal Treatment) :—

Favourable conditions of humidity and temperature give rise to fungal and mould growth on organic material in which there is plenty of nutrient material for the organism. Ideal air conditioning in museums is rare and so it becomes necessary to keep the exhibits sterilized. Sterilization is done by making use of various chemicals which render the feeding material poisonous for the growth and development of fungus, mildew and insects. In some cases, as in wood, heating is also used to sterilize the object, but for textile, paper, leather, it is harmful. Useful chemicals for sterilization are thymol, corrosive sublimate,

formaline (not for glue and leather which are rendered brittle) zinc chloride, zinc-silico-fluoride and sodium arsenite, etc. Aqueous solutions are sometimes harmful for pigmented material as well as for such objects as are composed of two different materials. The chemicals used in fumigation and sterilization get volatilized and disappear in due course of time and therefore periodic repetition of the processes is to be carried out according to necessity. As most of the chemicals are highly poisonous, their use is hazardous and therefore they should be handled with caution.

Elimination of Salts and Acids :—

The specimen are sometimes found charged with soluble salts such as chloride, sulphate and free acid. In the former case when the concentration is large, even aggregates are visible, while in the later if textile, paper, leather and cordage are involved even charring effect is noticeable, besides general fragility. With silver nitrate solution water extract of a chloride solution gives a milky white precipitate, which is soluble in ammonia solution. Barium chloride solution produces cloudiness with a soluble sulphate if it is in traces, otherwise a heavy white precipitate is formed. The presence of acid is tested with a wet blue litmus paper which is turned red. The soluble salts and acid are eliminated either by making free use of water such as steeping or wet paper pulp treatment, *i.e.* restricted use of water. The former process is no doubt quick, but it sometimes involves risk as in wood, bone, ivory and leather

where irreparable damage takes place. The water or the paper pulp is changed when it gets charged with salts and the treatment repeated until the salt concentration is reduced to minimum. The process of elimination of salts is watched by making tests with silver nitrate and barium chloride in the wash water. When the concentration of acid is large, it is sometimes neutralised with a dilute solution of ammonia followed by washing with plain water.

Paper pulp is made by steeping pieces of paper in water for a long time and beating the lumps with a wooden hammer till a fine pulp is formed. It is stirred well and in its final form resembles porridge. This pulp is flung on the object so that an uniform layer is formed all over, and a thickness, of about $1/8''$ to $1/2''$ depending upon the size of the specimen, is reached. When such a layer dries, it comes off in the form of a sheet. The paper pulp drags out the soluble salts on the surface by capillary action during the course of drying. There are cases when the antiquity being very fragile cannot stand treatment with even the thinnest coating of paper pulp and we have then to make use of wet sheets of good quality filter paper.

Strengthening and Consolidation :—

Antique objects are generally fragile, delicate and fragmentary and are in such a condition that it is sometimes impossible to handle or treat them without first strengthening them. Such cases are very common

in textiles, paper, ivory, bone and cordage. The manner in which strengthening can be done is by impregnation with an inert substance which causes the consolidation or hardening of the texture. Where chemical treatment for preservation is a necessity and the object is so delicate that it disintegrates on even handling or wetting with solutions, the impregnating chemical should be such that though it consolidates the fabric, the treatment of the material for preservation is possible. For example, age old salt saturated textile fabric is found to be reduced to dust if a drop of water is put on it, but if it is strengthened first complete elimination of salts can be carried out without any damage to it. Similarly bone and ivory objects immediately go into fragments if they are put in aqueous solutions for chemical treatment and preservation.

The impregnating materials should therefore not be completely impervious to water and should be such that they can be removed with ease when required. Sometimes strengthening is done by mechanical means as in ivory and bone when a thread is closely wound round the object before immersion in solutions for treatment. The thread counter-balances the forces resulting from the swelling of the object and thus does not allow the falling of the pieces. As a matter of fact semi-detached and very weakly-attached fragments of the object are held in position by the impregnating material. Wax, shellac, canada-balsam, celluloid, cellulose acetate, vinyl acetate, methyl-

metha-crylate solutions are good impregnating materials. The solution is used either with a brush, dropper or a sprayer. Strengthening is done before chemical treatment only in extremely delicate cases, and in other cases it is done after cleaning. It is not necessary for sound and solid objects.

Fixative and Adhesive

Textiles, paper and wood are sometimes painted and the paintings, drawings or designs are on backgrounds of different thicknesses. The treatment of such materials is complicated. The background and the painted surface show signs of decay and tendency to peel off. The cause is the decomposition of binding medium of the pigment and the plaster. A new binding medium is therefore introduced to fix the layers of the painting and the background. For this purpose transparent inert resinous materials like vinyl acetate and methyl-metha-crylate in suitable solvents are used. It is important that the solvents are not allowed to dry very quickly, otherwise peeling off of the layers takes place. Best quality materials are used for preparing the solutions. Use is made of a dropper, syringe, and paint-brush to introduce the adhesive and the fixative. Dilute solutions give better results and if one coating is not enough, two or more can be introduced till effective adhesion is obtained.

Preservative Coating

The objects after cleaning are still subject to agencies that tend to their destruction and the means

to protect them is to coat them with some preservative which is impermeable to moisture and acid. Quite a lot of preservatives have been tried in the past. Materials such as oil-paint, varnish, wax, shellac, celluloid and cellulose acetate solutions are not considered safer for some reason or the other. Some of them impart an undesirable colouration and decompose with time to produce harmful effects, they have therefore been replaced more recently with bakelite, vinyl and acrylate resin solutions which are reported to be giving successful results. Vinyl acetate solution of higher concentrations give glossy surface but methyl-methacrylate leaves a mat surface after treatment.

The treated objects are rendered porous after the removal of the surface incrustation and are susceptible to be affected liberally by the harmful agencies and therefore preservative coating is a necessity for their future preservation. Very porous objects are preserved under vacuum so that they get deeply impregnated and consolidated. The use of suitable solvents for preservative solutions plays an important part in making the preservative effective. Dilute solutions are preferable to thick solutions as the former have greater permeability than the later.

Repairing, Mounting and Backing

Repairing means refixing of broken parts in position. The broken parts need first be cleaned of all

the dirt, mud, etc., and then trials made with different pieces to see which fit in where. After fixing the positions they are joined with adhesives of known compositions. Great manipulative skill, experience, patience and care is needed for successful repairing. Repairing brings about the partial or complete assemblage of the object. The chemistry of cements, pastes and adhesives has sufficiently drawn the attention of Chemists and all cyclopaedia of chemical formulas have described a large number of them. Only stable material is to be employed as the cementing material. Glue, celluloid and such materials as are likely to decompose and produce acids and attract mould should not be used. Vinyl and acrylate resins give quite satisfactory results for repairing bone and ivory. Broken wood is joined and repaired with a mixture made of shellac, vinyl or acrylate resins, toluene, rectified spirit and wood dust.

Textile, paper and birch bark require mounting and backing. A special paste containing an insecticide is used as an adhesive. Mounting is usually done on silk, chiffon, silk gauze, Japanese tissue or Nepalese paper. Such reinforcing of the specimen increases their resistance to handling. The reinforced specimen are further mounted for proper support on card board mounts or stretchers if the specimen are of large size. The various types of mount boards used are the solid mount, the window mount and the overthrow mount. Mounting will be discussed in greater detail later on.

Restoration and Renewing

Unlike repairing, restoration means the addition of new material in place of the missing one with an idea to strengthen the object or to give it conjectural shape. Such restoration should always be judicious and definite and be fully supported by all the possible evidence furnished by the original pieces. It should be confined to bare necessity and be not superfluous. Original specimen however fragmentary or delicate it may be, is more valuable than the most perfect restoration work and this fact should not be lost sight of, when restoration is being done. The restored portions are brought to almost the same tint as the original so that they can be easily distinguished from the original. The pigments used for restoration are ocherous and as such are of permanent nature. Organic pigments are not recommended. Since textile and paper are strengthened by mounting and giving a backing, they are not restored generally. Bone, horn and ivory are restored with paraffin wax when considered necessary.

Leather

As already stated before each specimen has to be tackled in its own way for preservation, it would be better if for want of space the methods of preservation of only specific objects are given here after giving briefly the causes of deterioration. In the museum we come across leather objects which have become excessively dry, porous, brittle and cracked. They

are found to have lost all flexibility and suppleness and a slight bending causes them to break. Cleaning is done first with a mixture of water and alcohol and then with alcohol alone. The specimen is allowed to dry very slowly. Then a mixture of alcohol and castor oil is applied. A day after, another coat of castor oil is applied. If the leather is not softened by this treatment, then a dressing mixture as recommended by the British Museum consisting of lanolin, cedarwood oil, beeswax and hexane is applied. This is left over the object for sometime so that it can be absorbed by the tissues. Acidity in leather can be controlled by the application of a 7% potassium lactate solution followed by treatment with the dressing mixture. The dressing mixture is well-rubbed in so that it penetrates deep into the tissues for proper preservation. Leather requires regular periodic dressing. Such animal and vegetable oils as are likely to become rancid with age are to be avoided as the acid liberated starts eating away the leather. The condition of the material would suggest whether an oil or wax mixture is to be applied. Oil and dressing mixtures produce darkening effect, but this defect is counter-balanced by the effectiveness of preservation. Mounting of leather can be done on canvas with a wax and resin medium.

Leather book bindings are also similarly treated, but the extent of deterioration in them is found more marked, because in books, leather is tightly stretched and such a condition accelerates decay. Written

documents on leather are also similarly treated and mounted on canvas. Insects play the usual havoc on leather objects and when we find this menace, fumigation, usually with carbon-di-sulphide is carried out. Bacterial infection is controlled by washing with a dilute carbolic acid alcoholic solution before application of the dressing oil or mixture is done.

Textiles

These include simple woven or embroidered cotton and silk material or the dyed and painted objects. Cordage also comes in this class in as much as it also consists of similar material. The causes of deterioration are insect and bacteria, ugly stains and incrustations, creases and folds, brittleness due to varied temperature, and humidity conditions, contamination with acids, and salts. If the material is painted, it involves complications. The pigments get loose because the adhesive or the medium gets lost due to decomposition with lapse of time. The ground, if any, also behaves in a similar way. Preservation therefore calls for the removal of stains and incrustation, elimination of salts and acid, fumigation, sterilization, treatment for removal of creases and folds, strengthening if the fabric is brittle, fixing the loose ground and pigments if painted and then mounting on Japanese or Nepalese paper, gauze, muslin or silk. The final mounting is done on mount boards if the specimens are small and on wooden stretchers or rolls if they are large.

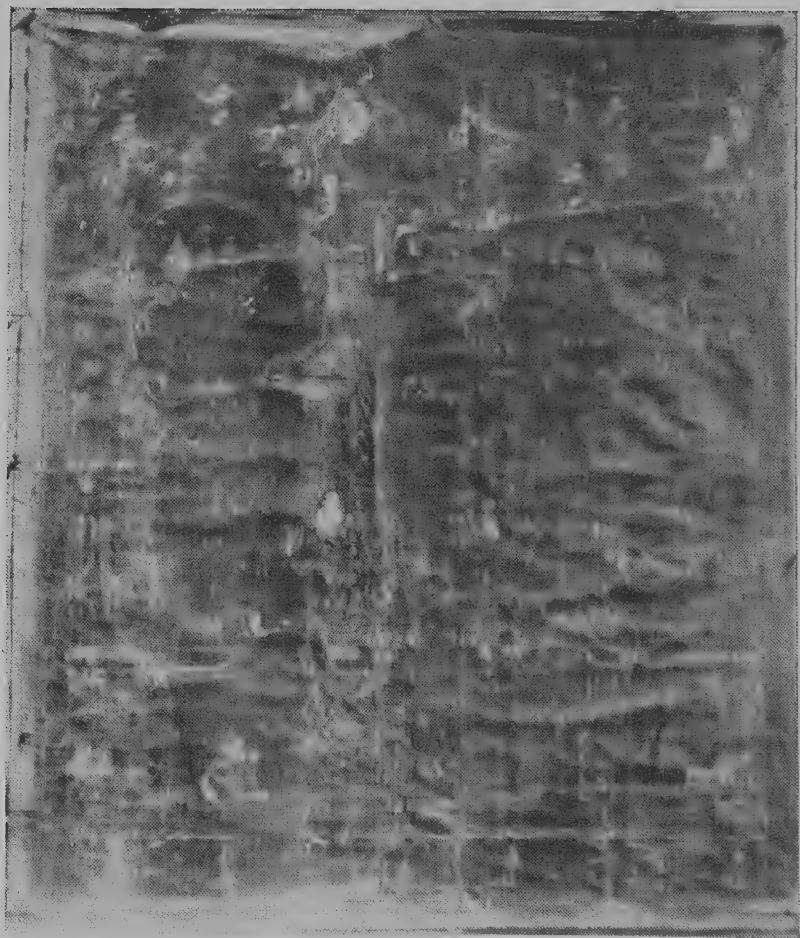
The chemicals used for the removal of different kinds of stains will be taken up in detail when dealing with prints, drawings etc. Let us here describe in detail the treatment of one of the complicated specimens of this class, *e.g.* a painting on silk, which has been affected by all the agencies referred to above. First of all dust is removed from the object with a brush or a vacuum cleaner with a muslin piece attached to its mouth. It is then opened out by flattening along the lines of folds and creases by applying a mixture of alcohol and water and pressing with a spatula. Thus the whole painting will get exposed and further treatment will be facilitated. If the fabric is difficult to be handled, it is strengthened with coatings of .5-1 % methyl-metha-crylate solution in toluene and alcohol—the number of coatings depending upon requirements. Strengthening also works as an adhesive to fix back the pulverised pigments. Unnecessary application of the strengthening mixture is to be avoided, as it would otherwise hamper the cleaning of the material. Fumigation with carbon-di-sulphide or hydrocyanic acid is then carried out to kill the bacteria. This treatment lasts for about a week or fortnight. The dead insects and bacteria are brushed off. Stains which require the use of organic and aqueous solvents are then removed in turn. If there are undesirable backings of paper, card board, cloth or silk, they are removed as far as possible. If there is salt menace, the specimen is washed in running water by subjecting it to a con-

tinuous flow of water if it can stand this treatment, otherwise it is pressed between wet sheets of blotting papers which are changed when they get saturated with salts. The treatment is continued till the salt concentration is reduced to its minimum. If there is high acid contamination, it is neutralised with dilute ammonia solution and washed thoroughly with water. In the case of painted material if the colours or pigments seem to be running with water, the washing treatment is immediately stopped and the textile allowed to dry slowly. When completely dry, the running pigments are again fixed with 5% vinyl acetate solution in alcohol; and when it has dried, again washing treatment is continued. During washing the specimen is laid on pasted sheets of Nepalese or Japanese tissue paper flattened over thick glass sheets. Such an arrangement facilitates the treatment. Washing and cleaning with solvents is done on both the obverse and the reverse sides otherwise the results are not effective.

The question then is to mount the specimen on some suitable mounting material. Mounting on silk strengthened by two coatings of Japanese paper (one applied horizontal and the other vertical) is the best to give support to fragile and brittle textiles, but if both the sides are to be exhibited then mounting is done between sheets of transparent materials such as glass, perspex etc. A mounting paste consisting of starch=1 oz.; sodium arsenite=14 grains; saffrol=.5 ccs.; water=8 ozs. has been found quite

satisfactory for the purpose. The painting can be kept as a roll, but then sometimes a little glycerine is necessary to be added to the paste to avoid cracking. Wooden stretchers are made by pasting two coatings of Nepalese paper to each side and then covering one side with muslin also. On to the other-side, the silk mounted painting is fixed by pasting along the edges only. The painting is never pasted all over. Such mounted paintings are then put in frames provided with glass in the front. For future preservation, wooden beading is kept between the glass and the painting so that there is some space left between the two surfaces and direct contact is avoided. Smaller textile pieces are mounted in mount boards—overthrow, solid or window type according to choice. If by chance textiles get damp, they are dried very slowly but not in the sun otherwise irreparable damage takes place.

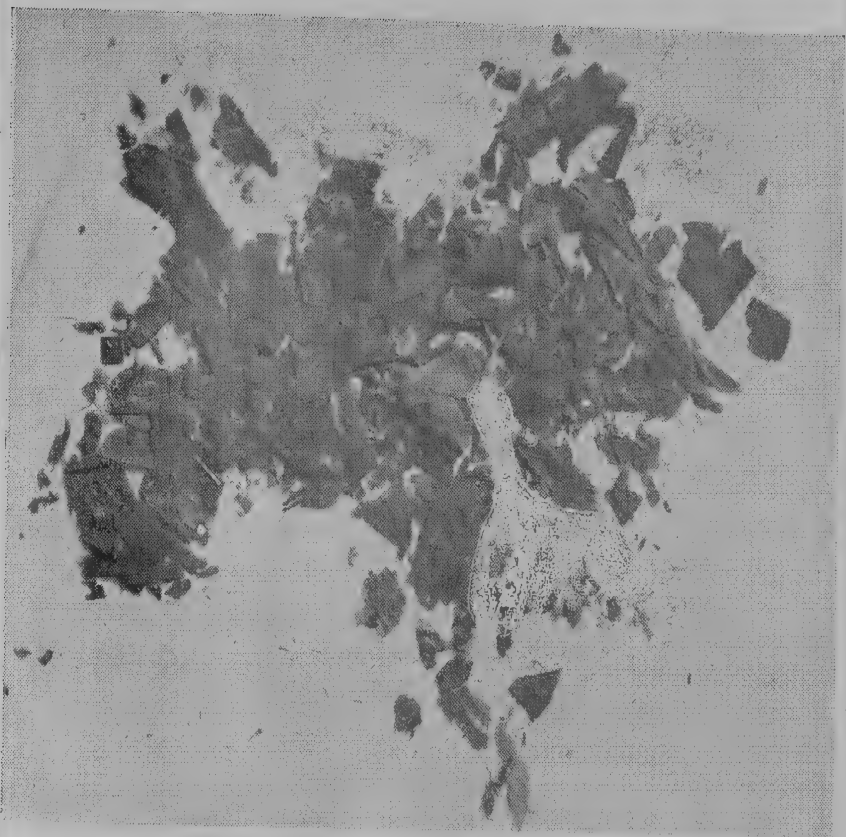
Photographs Nos. 1 and 2 show the conditions of a Tibetan Painting before and after chemical cleaning and preservation. The painting is on cloth and was originally covered with stains of organic nature some of which were very resistant. There was rancidity all over and the painting had blurred appearance. While the white pigment had tendency to flake off, all others were found pulverized. Photographs 3 and 4 represent the condition of a printed textile of the 8-9th century A.D. before preservation and after preservation respectively. Before preservation the textile was in a very fragile condition and



No. 1 Tibetan Tanka.
Before preservation.



No. 2 Tibetan Tanka.
After preservation.



No. 3 Printed silk 8-9th Cent. A.D.

Showing fragmentary condition before preservation.



No. 4 Printed silk 8-9th Cent. A.D.
After preservation.

even the small bits could not be handled safely. It was highly fragmentary.

Wood

Wood is a common material of utility and hence we have to deal with quite a large number of wooden objects in a museum. Deterioration brings about a change in the colour of wood and if it has advanced considerably then parts of it are lost and the shape also thus gets altered, but this is generally in extremely few cases. Prevention is better than cure and, therefore, if regular inspection and close scrutiny is carried, it goes a long way to prevent contamination with salts, insect damage and spread of infection. If there are borings and tunnels through which wood dust is coming out, it can be gathered that the agents causing decay are insects and their larvae. When there is incrustation and crystalline deposits on the surface which is rendered powdery, then it is presumed that soluble salts are playing their part. In certain cases the wood appears very spongy, so much so that even a little pressure with fingers causes depression on the surface. There is a net work of cracks running parallel to and across the grains and the wood has a tendency to shrink and warp. The cause is dry rot brought by certain fungi. Water logged wood also presents a problem for preservation. Bacterial infection which is responsible for human diseases is reported to have no destructive effect on wood.

It is not uncommon to find objects which are affected by more than one agencies of decay. Wooden

panels are sometimes painted and lacquered. In such cases the causes of decay of paint and lacquer material also come into play, and when all these combine, the question of their preservation becomes more complicated and sometimes very difficult to tackle effectively. Preservation, therefore, calls for the eradication of the causes of decay, sterilisation of the material and the consolidation of the texture. Insects, beetles and larvae are killed by fumigating the objects in closed chambers with carbon-di-sulphide alone or with a mixture of carbon-tetra-chloride and ethylene-di-chloride for a number of days. Large size wooden objects having long tunnels bored by beetles are injected with the insecticidal chemicals with a syringe and the holes plugged. Both fumigation in the chamber and injection with the fumigants have many a times to be repeated in order to make it effective, as some of the insects and their larvae are very resistant. Vacuum fumigation is preferable in such cases. Oils etc. which produce stains are not used as they produce ugly patches and are not at all suited for painted wooden panels. Strongly smelling preservative chemicals are not desirable for museum exhibits.

Soluble salts generally found responsible for deterioration are sodium, calcium, magnesium chlorides and sulphates. If the object is inscribed with water soluble ink, or is painted, the written material is fixed with 1 % methyl-metha-crylate adhesive. Salts are removed by paper pulp treatment as already

explained. The dry pulp is removed and washed free of the absorbed salts and applied again. The nature of the object determines the thickness of the pulp layer. Complete immersion of the object in running plain water is not desirable as it causes the wood to swell and warp which results in irreparable loss. In case of treatment for the elimination of salts in painted panels, wet blotting paper sheets are pressed to absorb the salts and these are repeatedly changed but, if the pigments and ground have become loose, they are first fixed. Drying is done very slowly—first with alcohol and then between sheets of dry blotting paper. Wood thus freed from soluble salts is porous, and therefore it is impregnated with a 5% solution of vinyl acetate or .5% methyl-methacrylate which render the surface hard.

Though dry rot aptly describes the brittle and dry appearance of the wood after attack, it is a misnomer for the trouble, because the fungi causing the decay require a certain amount of moisture before they can attack and some of them actually produce water from the wood by their life processes. For sterilisation the object is heat treated at about 130°F. for about six hours to kill the fungi. Use of wood preservative solutions of sodium fluoride, magnesium-silico-fluoride, zinc chloride, etc. are used with successful results. The preservatives are either applied on the surface or the objects are dipped in the solutions. In case of dry rot affected painted wooden panel, alcoholic solutions are preferred to aqueous solutions. The

porous surface is hardened with 5% vinyl-acetate solution in a mixture of alcohol and toluene.

Water logged wood is allowed to dry very slowly by keeping it packed with sawdust or husk. Then it is kept in alcohol to replace the absorbed water and when perfectly dry, a coating of 5% vinyl acetate solution in alcohol and toluene is given to fill in the cavities. Another method of filling up the cavities is to use a mixture of glycerine and alum. The use of 5% vinyl-acetate gives better results. Filling the wide cracks and joining small pieces of wood is done with the mixture already given before.

Photograph 5 shows the condition of an ancient wooden object 3rd century A.D. from Niya site in Central Asia. The accumulation of surface incrustations consisting of calcareous material and soluble salts can easily be seen on the surface. The cracks are due to warping caused by dry rot. Photograph 6 shows its condition after elimination of salts and treating the object for dry rot.

Reed, Straw and Matting

Reeds, grasses, etc. have been in use since very early times for making articles of utility. These articles become very dry and brittle with age. In very moist weather, fungal growth also appears on them. Their general cleaning is done with a dry brush followed by cleaning with alcohol, petrol, etc. to remove dirt, grease, etc. Fungal growth is checked by fumigation with thymol. Water is not used for



No. 5 Wooden object.

Showing incrustations of salts and cracks due to dry rot.
Before preservation.



No. 6 Wooden object
After preservation.

cleaning as it has a tendency to disintegrate the fragile objects. Strengthening of the fragile articles is invariably done with solutions of 5% vinyl acetate or .5% methyl-metha-crylate. Melted paraffin wax is also used sometimes for this purpose.

Feather and Hair

Feather and hair are very tender material. Hair is resistant to ordinary influences of decay but feather is rendered brittle with age. Hair is cleaned of grease with alcohol, toluene etc., cleaning of feather is rather risky and hence for preservation it is coated with the preservative solutions to strengthen them after fumigation. Periodic inspection is necessary to guard against insect attack.

Birch Bark and Palm Leaf

Birch bark manuscripts though rare, are important in-as-much as they are very old. The specimens are very thin and due to age they are rendered dry and curled and become brittle. The only way to make them pliable is to treat them with steam and then mount them between transparent material for future preservation. Sometimes a mixture of alcohol with the minimum quantity of water is also used for this purpose. Fungus also grows on it under high humidity conditions for which application of 5% thymol solution in alcohol is found suitable.

Palm leaf illustrated manuscripts are found stained with flymarks. They should not be treated liberally

with aqueous solutions as the fibres undergo expansion or wetting and contraction on drying. For cleaning, a mixture of alcohol and water, alcoholic solutions of hydrogen peroxide and chloramine T. are used successfully. If the pigments of the painting and the carbon ink get loose—which it is generally not, they are fixed. As the manuscripts are often written on both sides, they are mounted between transparent glass sheets for preservation.

Ivory, Horn and Bone

Ivory, horn and bone form one class so far as treatment is concerned in-as-much as in their cleaning the use of water is to be avoided as far as possible and if at all necessary, only restricted use is to be made. Water causes uneven swelling of the material and therefore it causes warping. Old ivory is found to have pale, yellow, golden, brown and black colour. Bone is liable to disintegrate more than ivory. Generally we come across hard earthy and calcareous deposits as well as soluble salt incrustated on the surface. These objects are subject to the attack of insects for which fumigation as described earlier is the remedy. Old bone and ivory are found fissured, exfoliated and porous. They become brittle and are very fragile to be handled and exhibited. In the case of bone the inside is generally spongy but ivory and horn are not so. Fumes of acids affect the natural colour and produce deleterious effect on all these. Chemical processes of softening are particularly risky as the surface naturally softens first and is readily destroyed.

The treatment of this material involves the removal of dust and loose mud by brushing with a dry brush or pointed splinter and pins. Cleaning is facilitated with methylated spirit or alcohol alone or its mixture with the minimum required quantity of water and aided with brushes. The adherent earthy matter is loosened by this process. Stains are removed with hydrogen-per-oxide or ozone. For elimination of soluble salts, the object is given one or more coatings of a strengthening mixture of 5% vinyl acetate or .5% methyl-metha-crylate which form a protective layer and do not allow the splitting and disintegration of the material. These protective coatings are permeable to water and the soluble salts can be leached out easily. In case of incrustations of calcium-carbonate and sulphate, dilute 1-5% hydrochloric acid solution is used to dissolve them out. Treatment with acid solution is continued till the effervescence continues. The object is then washed thoroughly in plain water until, when tested with silver nitrate solution, no white precipitate is obtained in a sample of wash water. The coatings of the strengthening mixture are not enough to prevent the rupture of the object if a very prolonged treatment for elimination of soluble salts and calcareous incrustations is necessary. The coatings give way during the course of treatment. Specially in fragile objects the protective effect is not enough. Therefore the safest course is to wrap the object after impregnation in a muslin or gauze and pass a thread all over and then, subject it to water

or acid treatment. Such an arrangement proves quite sound.

When aqueous treatment is completed, the threaded object is dried through a number of alcohol baths and then finally in air in atmospheric conditions. The gauze and thread are then removed. A vacuum desiccator is also used for this purpose if necessary. The protective coating during all these processes get disturbed and hence it is desirable to remove it with toluene or ethylene-di-chloride. Impregnation of the specimen for consolidation is best under vacuum with .5% methyl-metha-crylate solution and for this the specimen is dried well before hand. In certain cases the preservative is applied once again on the surface with a brush after vacuum impregnation. Impregnation with wax is not very satisfactory and hence wax for this purpose is not recommended now in view of other more efficient impregnating materials. Moreover, impregnation with wax involves heating of the object, which is full of all risk.

Repair and restoration is carried out by making use of hard paraffin wax. Such cements as shellac, glue, etc. as are likely to stain ivory should not be used. For joining pieces, 6% methyl-metha-crylate or 50% vinyl acetate in toluene are found quite satisfactory. They do not produce any staining effect and take some time to harden up. This helps in adjusting the fragments correctly. Wax used for restoration is tinted with a little quantity of bitumen so that a pale colour matching ivory or bone is obtained. It



No. 7 Bone object as recovered from excavation at Rugar.



No. 8 Bone object from Rugar after proper preservation.

is easier to mould the restored parts with wax than with plaster of Paris which is also sometimes recommended for this purpose. For very large objects plaster of Paris may be used. The wax restored parts are generally softer than the specimen and they appear so especially during the hot weather and therefore a thick coating of 25% vinyl acetate in toluene or 1% methyl-metha-crylate solution in toluene is given to the restored portions to make their surface hard. More than one coating may be necessary.

Photograph 7 gives an idea as to how a bone handle was recovered from excavations at Rupar. It was in fragments and was fragile and embedded in hard soil. Photograph 8 shows its condition after preservation.

Paper (Prints drawings, and manuscripts)

From considerations of conservation, it is of utmost importance to study the physical and chemical composition and manufacturing methods of paper. It is desirable also to know the physical history of the object as it can throw light in understanding the causes of deterioration. All these contribute to the permanence of the material. Paper is made exclusively or nearly so of fibrous cellulose. Almost every known fibrous material has been tried for the manufacture of paper. The quality of the paper depends upon the source of the material and the different chemicals used in its manufacture. Therefore it is necessary to study in brief the method of the manu-

facture of different kinds of paper (thin, heavy, coloured) which are liable to become brittle, stained and mildewed with age and wrong mode of storage. It will then be easy to understand their behaviour towards the various agencies of decay as also the problems of their cleaning, reconditioning and future preservation.

For writing purposes, primitive people used stone, clay, palm-leaf and bark of plants, and the first sheet material, which can be considered as the forerunner of modern paper, appeared in China about 1700 years back. The Chinese started its manufacture from bamboo and later on the Arabs followed them and used linen, cotton, rags, flax and other vegetable growth yielding suitable fibre. The evolution* of printing presses created a demand for large-scale manufacture of paper and co-ordinated efforts were made all over the world to produce paper of different kinds by improved scientific methods, and consequently the manufacture of hand-made paper gradually dwindled away. In India we have still hand-made paper used for certain specific purposes though manufactured paper has now replaced it for other purposes.

The outstanding source of cellulose fibre is wood. About 90% of the worlds produce of paper is from wood fibre. Waste paper is also extensively used to prepare pulp for paper manufacture. Rags, straw—largely of wheat or rye, jute, hemp fibre, cornstalk

* The oldest known printed MSS appeared in 868 A.D. in China,

and cotton are also used for this purpose. Paper produced from strong wood pulp have improved permanence or aging characteristics. Chemicals and inert material as sulphur, caustic soda, soda ash, lime and chlorine, alum, rosin, clay, talc, barytes, zinc and titanium compounds are used for improving the quality. Dyestuffs employed for colouring paper are principally of the aniline type rather than pigments or natural organic dyes. In ancient specimen we do not come across coloured paper. The main features of paper manufacture are as follows : The fibrous raw material is made into pulp either by mechanically grinding it through very strong grinders or by treating it with chemicals like caustic soda, calcium hydroxide or calcium sulphite. The former kind of pulp is generally used to produce newsprint, wall paper, wall board and paper board, while the later unbleached quality is widely used in newsprint, boards, wrapping papers and certain grades of printing papers, where reasonable light colour, good strength and flexibility are required but where cleanliness is not so important. Bleached pulp is used in writing and typing papers, tissues, greaseproof paper, printing papers and in the higher grades of wrapping paper. The pulp is made to flow slowly with water through a series of sieves and screens so that all chemicals get washed and the pulp suspension freed from large and small size fibres. During this process the cellulose fibres arrange themselves along the lines of flow as the pulp passes through the machine. It is then

passed over driers and between hot rollers before the sheets are formed.

When it is desired to bleach paper, the bleaching reagent is added to the pulp before washing. In order to impart brightness, smoothness and opacity, loading or filling agents which are natural mineral substances, *e.g.* clay, chalk, talc, barytes, etc. are used in the pulp suspension. To render paper somewhat water resistant, sizing is done with rosin, starch, glue, casein etc. The grades in which paper is marketed are tissue, wrapping, writing, printing, book papers and boards. Best drawing papers are not loaded, but they have to be sized to prevent colour spreading on application. The sizing materials are good nutrient for moulds and hence their use from the point of view of permanence is undesirable. In bleached paper there is less susceptibility of infection but if the bleaching agent does not get thoroughly washed, the paper remains acidic and is liable to become brittle and perish at an enhanced rate. Heavily loaded paper gets sticky when damp.

Paper can be described as a permanent material under ideal conditions of storage. Old papers are generally found to be absorbent and brittle. They slowly absorb moisture which promotes gradual atmospheric oxidation of the cellulose, and size, and decomposition of the loading material and in due course get destroyed. Stains are caused by such decomposition, foreign deposits and incrustations such as fly, grease and ink stains. Paper loaded with cal-

cium carbonate is more resistant to natural ageing. The oil used in printing has deteriorating effect on paper, because it gets oxidised and liberates acid. Certain papers become red due to the oxidation of iron contained in them. Except that under humid condition, starch and glue encourage mould and insect attack, they do not, as far as is known, cause any deterioration of papers. Rosin increases the tendency of paper to deteriorate. Chemical examination is therefore necessary in identifying the various constituents of paper and in determining whether or not it is made of highly resistant cellulose or if any deteriorative materials have been used in the manufacture. This would reveal the causes of disfigurement and help in adopting preservative methods.

For purpose of examination the sources of paper making fibres are divided into (1) the cotton group, (2) the wood pulp group, (3) the grass group and (4) the rope group. Each kind of fibre shows a distinctive feature when photomicrographed and examined under microscope and this provides the most convenient, and in some cases, the only means of identifying its various constituents of paper. Chemical tests, to cause characteristic colour in the various fibres, are carried to identify them. Similarly loading, filling and sizing materials are also identified by their characteristic tests. High available acid in paper causes quick deterioration, and therefore its determination is also necessary.

Light, heat, composition of air as to its moisture and acidity contents and ageing are important factors governing durability. In these days of efficient artificial light, there is a good deal to be said for the complete elimination of natural lighting altogether. Direct sunlight should always be avoided so far as possible. The effects of most of the deteriorating influences which act on paper are accelerated at higher temperatures and the higher the temperature the greater this accelerating effect. This statement applies more to the effects of acidity than to any other single factor, it also describes the effects of exposure to light, although of course light is much less potent than heat. Both light and heat become more active in the presence of moist air.

Inks

The earliest types of inks are mixtures of lamp black or soot and glue or gum well pounded together. These inks are very stable and being free from excessive acidity have no deleterious effects on paper. Chinese and Indian inks have this composition. These inks, of late, have been replaced by iron gall inks which are also permanent, but they are liable to be acidic due to tannic acid and therefore attack paper. Some of the pigment colour inks are permanent but some of them are not, and are notoriously susceptible to atmospheric acidity. Some of the common pigments are given below in order of their fastness:— Ultramarine, cobalt blue, prussian blue, chromium oxide, Indian and venetian red, the siennas, vermil-

lion, madder lake are more or less permanent but natural indigo, gamboge, vandykebrown, carmine, purple madder and crimson, are reported to be poor, when experimented upon. Inks from aniline colours are inert towards paper but are fugitive. Sepia is a preparation from the dark-colour pigment discharged by the common cuttle-fish in order to cover retreat when attacked. It is much less permanent than is usually thought. Printing inks are compositions of pigments and oils or varnish. They are permanent but the oil medium (vehicle or binding material) attracts moulds. Medium plays an important part in the life of an ink or pigment. Insufficient medium in ink causes detachment of the pigment from paper and it requires some fixative to fix it back.

Water-Colour Pigments

The pigments in water colours have gum medium and when they are applied to paper the fibres pick them up and get fixed as the moisture evaporates. It does not come out easily even with water. The pigments of some of the Indian paintings especially Rajasthani and Mughal where they are thick are not very well fixed and have tendency to flake off. The requisite tints are produced by mixing two or more colours or by superimposing one colour on another. The toning effect is sometimes lowered by the chemical interaction of certain pigments and this is hastened by exposure to sunlight and damp. Water colours are liable to fade by sunlight and visible light more

so in presence of moisture. Decomposition of certain unstable pigments such as verdigris and Indian yellow also takes place and the colour scheme of the painting changes. Lead pigments and silver tarnish rapidly in atmosphere containing hydrogen sulphide gas. During cleaning, care is to be taken not to use such chemicals as would affect the colour scheme of the painting.

Other Drawing Materials

Other drawing materials include, pastel, chalk, graphite pencil, silver and gold point paintings. Although colours of pastel and chalk paintings are chemically stable, they are held loosely to the ground and are liable to be damaged by rubbing and mechanical vibrations. Certain types of drawings become more stable with time probably owing to the action of moisture and oxygen. The quality of work is lost by fixative. The gum and size are easily infected by spores and the drawings are thus liable to mildew attack. Graphite pencil drawings also become fixed with time. Silver and gold point drawings are generally permanent. Lead pencil drawings loose colour-lead being converted into white lead basic carbonate.

Fungi (Mildew, Mould) and Foxing

Fungi including mildew and mould constitute an important class into which the Thallophyte group of the plant kingdom is sub-divided. The names fungi, mildew and mould are generally applied indifferently to a large number of fungi, but some of the

more common ones are especially distinguished. Fungi are colourless and live either as parasites or saprophytes (living on decayed material). The typical vegetative structure of the fungi is a filamentous and much-branched thallus called a mycelium. Moulds are a type of fungi. A growth of it can readily be obtained if fresh horse-dung, or bread which has been soaked in water is kept under cover for four or five days at a moderate temperature. It makes its appearance in the form of little white patches which gradually spread and unite. Mildew also is a kind of fungus some what resembling a cobweb and ramifying in all directions over the surface. There is no chlorophyll in fungi and so they cannot make use of the carbon-di-oxide of the atmosphere. In a parasitic fungus the threads or filaments (hyphae as they are called) penetrate the living cell of the host or simply ramify between the cells. The power of penetrating and disorganising cell walls, which such hyphae frequently possess, is due to the secretion at the tips of the hyphae of a ferment which acts on cellulose. The hyphae of a saprophyte spread out through decaying organic substance or grow immersed in organic solution.

The harmful results arising from these minute fungi are formidable and unfortunately they possess most effectual means of increase, for the mycelium creeps into the tissue of the paper and thence spreads gradually throughout the whole surface, practically destroying all its texture. At times these may seem

to be only a few spots, but it is well to remember that the actual mildew, as it appears to the observer, represents only a fraction of the system, being simply that part which is concerned with the production of spores. The spores of the fungi are present in the air and the organism can find sufficient food and nutrition in paper and organic material to nourish them and thrive rapidly in temperatures, between 70°-90°F., a relative humidity above 65%, moderate darkness and supply of oxygen.

Paper is said to be mildewed, when it is weakened and stained as a result of the growth of minute fungi. With prints, drawings and manuscripts the damage may be considerable. Some moulds puncture the paper, others tunnel the tissue and others again, seem to work entirely on the surface. Disfigurements due to fungi occurs either due to its growth on the surface or interaction of the growing organism with materials already existing in the paper. This sometimes results in staining or increasing its effect. Though superficially, fungoid growths upon paper are very similar, great difference in their structure and habit is noticeable under microscope. In a particular mildewed area a wide variety of fungus may be present. Deterioration may be taking place without any recognisable signs of active growths.

Foxing

Old paper bears characteristic brown spotty type of discolouration. At some places there are brownish

spots and at other white and these are very disfiguring. This discoloration is called foxing. Foxing in paper is surrounded by many variable factors, such as, the nature of the paper, sizing, loading, ink and contamination with different fungi. One of the reasons for foxing is that the iron present, as an impurity in paper, gets attacked by the organic acid liberated from cellulose by the fungi. Organic iron salts are thus formed and they get unevenly distributed throughout the paper according to the conditions of humidity and porosity. Then they eventually get decomposed and oxidised into ferric oxide and hydroxide of iron which contribute to the formation of brown spots. Chemical tests show the existence of uneven distribution of iron. This is called positive foxing.

Another type of foxing is also sometimes observed on paper. Experiment showed that pale, brown paper which contained enough iron to impart colour, possessed clear spots dispersed on the coloured surface in the manner of fox marks when stored for three or four years in a damp room. The size of the paper at these spots had decayed and it behaved like blotting paper and when wetted absorbed moisture and retained it. Chemical tests showed that the quantity of iron at these spots was much less than in the rest of the paper and this accounted for the white appearance of the spots. The paper was found to be damaged by fungus and the unequal distribution of iron content in paper was thus attributable to the effect of fungus. This

phenomenon is called negative foxing. Thus it is seen that paper containing iron is so attacked by different kinds of fungi that the spots get either heavily charged with iron oxide or are deficient in it, but in both the cases the material suffers and the size gets destroyed. The loss of the size results in the loss of flexibility and the risk of breaking is enhanced. Since foxing is the result of fungal affection, high humidity is a favourable condition for the menace.

Moisture and Fungi

The growth of fungi as will be clear from above, takes place under certain humidity conditions favourable for its development. There are limits of humidity and temperature in which the fungi can thrive best. Humidity range of 40-60% with temperature variation between 50°-75° F. are considered to be detrimental to the growth of fungus. Also excess dampness has an inhibitive effect on its growth. Paper impregnated with an aqueous solution of the nutrient material was examined for appearance of fungus and foxed spots, and it was observed that the growth did not take place until evident moisture had dried out and it took several weeks for the foxed spots to appear. When the material is saturated with moisture, its cell spaces are entirely filled with water, and there is no fungal growth because it contains no air to provide them with oxygen. Different types of fungi have different degrees of resistance to temperature and humidity ranges. It should not be forgotten that certain

organisms can live in comparatively drier atmosphere. They have the property of absorbing moisture from the surroundings and therefore even under approved conditions, the possibility of certain forms of attack must not be overlooked. The constituents of paper are hygroscopic and they impart this property to it, more so when it is old and this explains to a great extent its proneness to become mildewed. Manuscripts, drawings and prints which are framed or packed tightly together for long periods are liable to fungal attack more frequently than those which are exposed. This is the result of bad ventilation which causes stagnation and results in the production of foul air which is conducive to fungal growth.

Sterilisation

Having known so much about the habit, mode of life, growth and the damage caused by fungi, let us now describe the measures that are recommended to be adopted for the eradication of the menace. If the existing growth is to be rendered inactive, and the development of spores is to be prevented in paper it is necessary (i) to avoid dampness, (ii) to destroy as far as possible the nutrient material and (iii) to allow free exposure to light and air. Sterilisation process should therefore satisfy these conditions. It should be adequate for the purpose in view, be simple enough to be within the reach of all and not involve the use of any harmful substance, nor should it have the liability of an accident.

The simplest way of avoiding dampness in prints, drawings and manuscripts would be to expose them to sunlight. Though it is useful to some extent, it is not convenient and very effective to highly infected material. Also certain pigments and ink materials are liable to fade or change colour in sunlight. Ultra-violet rays can also be used for sterilising purposes, but the details and manipulations are to be worked out carefully. Desiccation by heat or vacuum would mean dehydration of the paper and it may result in its ruin. It has been found that among sizing materials, alum and resin have inhibitory effect upon fungal growth and discoloration, while gelatine is easily attacked by them. The action of different sterilising agents varies greatly in intensity and therefore the choice goes for a fungicide to be applied in such a way that it would effectively satisfy the conditions laid down above.

Thymol vapour destroys mould in a closed space but it will not prevent a subsequent growth. During the last few years far more stable toxicants have been produced and shown to have effective properties as mould preventives. Among these are the phenyl-mercury compounds and the chlorinated phenols, especially penta-chlorophenol in organic solvents or for aqueous solution, sodium penta-chlorophenate. Use of solutions in organic or aqueous media is not desirable for manuscripts, drawings and prints, because they will get damaged; besides, the application process would also not be conveniently possible. The fungi-

icide is never effective unless it reaches the seat of infection. For these reasons gases and vapour producing solids are best. The vapour of a boiling liquid also has the disadvantage that the condensed liquid would be finely dispersed in the paper and may cause some staining effect. Use of chlorinated compounds is to be avoided for fragile and age old specimens as they may cause bleaching of the pigments and decay of the paper in the long run. The solids to be used should preferably have a low melting point, an easy volatility and should be readily available in pure condition. These conditions are satisfied by thymol and for this reason it is widely used as a fungicide and its efficacy with different types of infected materials tested very thoroughly. The success of sterilisation depends on (i) the concentration of thymol vapour reaching the fungus and (ii) the drying action which attends the slight rise in temperature.

It should be remembered that no permanent immunity can be expected from sterilisation by thymol and as such, objects which are once sterilised will be subject to further attack by mildew if returned to the infected cases. Thymol fumigation therefore has to be repeated more often if storage conditions are such that they cannot be improved for some reason or the other. It is of utmost importance to find the cause of fungal growth and try to eradicate it before thymolising the objects. It is important to note that thymol fumigation should not be carried out in the

case of oil paintings and varnished material as it softens them.

Sterilization Chamber

Here a brief description of the sterilization chamber, as in use in the National Museum, New Delhi, is given. The chamber is an air tight teak cup-board with an overall inner space of 4' 10" x 3' 9" x 2' 5" and stands on wooden legs 7" high. It is partitioned in the middle, each half has two removable stout wire netting shelves dividing the chamber into three parts each 10", 24" and 8" high. In each half is fixed, outside the base of the cup-board, an electric 100watt. bulb. Over the bulb the base is cut circularly where watch-glass 6" diameter can rest for holding thymol (melting point 50°C) which gets vaporised with the heat emitted out by the electric bulb. The doors are glass panelled, so that inspection can be carried out from outside. When the material is to be sterilized the current is switched on for about an hour or so and the chamber kept closed for 24 hours.

The position of the documents and books is changed after intervals of 24 hours and the chamber charged again with vapour with such frequency as may be necessary. The degree of infection determines the period of effective sterilization. The chamber is throughout maintained saturated with thymol vapour. Specimens are removed from the chamber after suitable intervals for inspection and the dried fungus is dusted off with cotton or fine brushes some-

times aided with alcohol also. No harm is reported to have been done by overdosing specimen of prints, drawings, manuscripts, pastels, water colour paintings, books, etc. Thymol disappears from the specimen in a few days and hence an assurance for its harmless behaviour to these objects can be given.

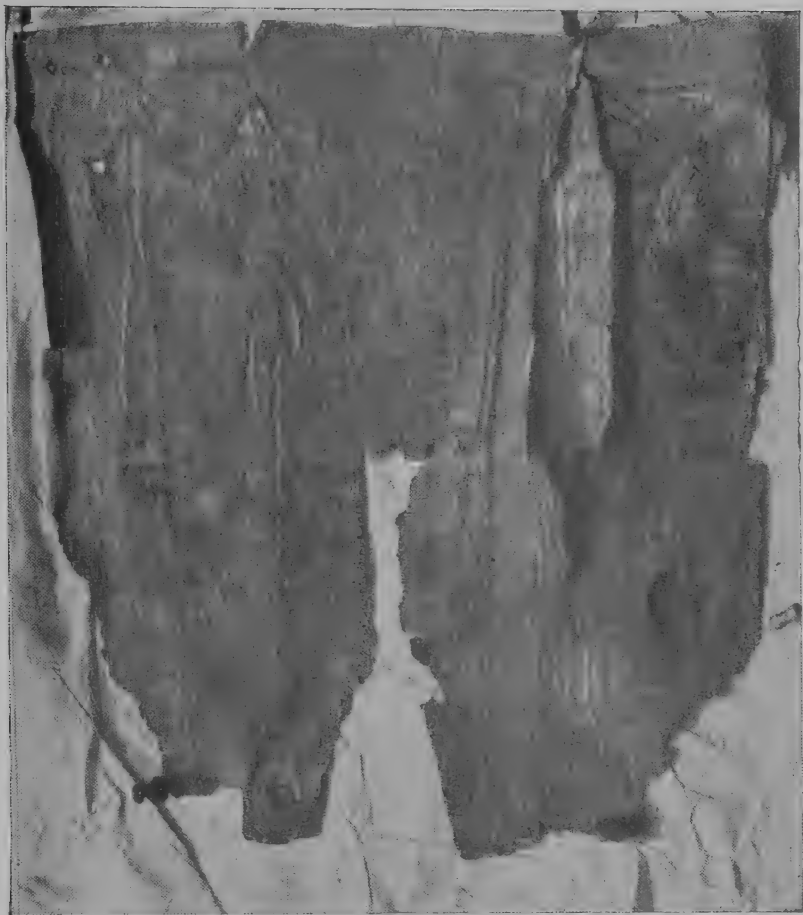
Chemical Cleaning

There are several aspects of this problem but for want of time I shall limit myself to only a few of them, which commonly confront those, who are concerned with preservation. Paper is very soft and porous and on moistening, it expands and the binding material is weakened. In such circumstances if delicate manipulative skill is not exercised, it gets torn on account of the wetted fibres slipping over each other. Before chemical cleaning is taken up, the specimen is always supported with a back paper, otherwise during the different processes of cleaning it may get damaged. In painted and written paper, the colour and the ink are likely to get detached and float away on wetting. From practical point of view ordinarily this class of objects is divided into two categories, drawings, prints, manuscripts (1) which are not mounted, (2) those which are mounted on paper layers or card-boards. Their modes of treatment for preservation are slightly different and are given below :—

(1) The print is first of all cleaned of the surface dirt with a fine sable brush, which is generally possible

except in the case of water colour paintings which are executed on a thick gesso ground laid on paper or when the paint layer is sufficiently thick as in the case of some Rajasthani and Gujarati paintings. In these cases even dry brushing removes the pigments. Therefore the pigments have first to be fixed with fixative solutions mentioned earlier. Then the folded pieces and the creases are dressed by applying a mixture of alcohol and water along the lines of fold and creases and pressed well with spatula. At times when there are innumerable creases and folds, the drawing or the print is left pressed with a thick sheet of glass. The specimen is then placed on a sheet of Nepalese tissue paper, which in its turn rests on a glass sheet which can be kept inclined. At obscure corners of the painting trials are made, to see if each pigment and ground can stand wetting treatment, and if not, suitable preservative coatings are given to the areas from where the pigments and the ground have a tendency to come off. One or more coatings of .5% methyl-methacrylate solution in toluene and methanol (75 : 25) or 5% vinyl acetate solution in toluene and alcohol (50 : 50) are given to fix the pigments so that they do not run down when treated with aqueous solutions.

The removal of stains by specific solvents will be taken up later and so only a passing reference will be made here. Stains, requiring the use of organic solvents, are then removed by applying swabs of cotton dipped in suitable solvents. When the stains have been removed from one side, the picture is turned upside



No 9 Block print on paper/
Central Asian 8-10th Cent. A.D/
Before preservation.



No. 10 Block print on paper
Central Asian 8-10th Cent. A.D.
After preservation.



No. 11 Painting on paper
Central Asian 8-10th Cent. A.D.
Before preservation



No. 12 Painting on paper
Central Asian 8-10th Cent. A.D.
After preservation.

down to expose the other side and stains similarly removed from this side also. The specimen is then again reversed and treated with aqueous solutions for removal of other stains. It is not necessary to carry on cleaning until all traces of the stains have disappeared as the last 25% will fade out on the print being dried, and by discontinuing the operation at about this point over-removal of stains or bleaching of the paper is avoided. The stains from the back side are also similarly removed. Thorough washing with water is a necessity to eliminate all the chemicals used for cleaning.

Photographs 9 & 10 represent the condition of a 8-10th century Central Asian Block print on paper. The specimen was in a crumbled condition and was full of stains and dirt rendering the drawings and the writing illegible. Successive treatment improved the print revealing the details completely. Photographs 11 & 12 show a water colour painting from Central Asia 8-10 century before and after preservation respectively.

(2) Paintings, drawings, manuscripts and prints which are mounted in a faulty way on coatings of paper and thick boards have to be removed from the back support. Here the pastes are generally starch, gum and glue which require softening with water. In the case of water colour paintings, prints and manuscripts which are likely to come off with moisture, the pigments, ink, etc., are suitably fixed as before and then the

specimen is turned face downward on a sheet of Nepalese tissue paper laid on glass plate. The board or the coating of paper is kept soaked in water for a few hours, when the mountant will become loose. In case there is likelihood of the pigments softening with moisture, then they are first fixed. The card-board layers are removed one by one, leaving the front side unaffected. Sometimes it becomes necessary to remove these layers by rubbing with fingers. Great care is to be exercised with the last layer which is in direct contact with the specimen. Sufficiently moistened mounts come out successfully, without causing any distortion or rupture of the surface. During the course of removal of the different layers of the mount, the adhesive has to be loosened with a paint brush. When all the layers are removed, every trace of the adhesive is removed otherwise on drying the specimen will not present an even appearance. A touch on the surface will make sure whether all of it has been washed off or not. This having been completed, the specimen is now ready to undergo chemical cleaning treatment as in the previous case.

Photograph 13 shows a Rajasthani painting which had been torn at several places and was found mounted in a faulty way. Its pigments came off even on touching it and the painting had a dull look. After preservation the painting came out very well as shown in photograph 14.



No. 13 Rajasthani Painting
Before preservation.



No. 14 Rajasthani Painting
After preservation.

Stains and their Removal

Varnish :—

The usual stains on prints, drawings, manuscripts, etc. are varnish, ink, flymarks, water-marks, tea, coffee stains, foxmarks, salt incrustation and oxidation products of specks of impurities in the paper itself. There are cases when manuscripts are coated with varnish. These varnishes, due to oxidation and ageing, turn pale and brown, and ultimately show tendency to crack. The manuscript thus becomes blurred, and the paper on which it is written also gets cracked. For its preservation, removal of the old varnish is absolutely necessary. Alcohol or its aqueous solution is used to remove the old varnish. In order to arrest the deleterious effect of the solvent on the paint, turpentine oil is used. More resistant varnish is removed by making use of 2% dilute ammonia solution, acetone, ether, pure alcohol etc., but these have also to be used cautiously lest the pigments may get affected. Swab of cotton dipped in the restrainer should always be ready at hand to arrest, whenever needed, the undue action of the solvent. In cleaning the print of varnish, start is to be made with the weakest agent and then worked upwards in strength.

Bleaching :—

Bleaching agents are materials which cause the discharge of colouring matter. They could be employed without imposing any restriction on their use for this purpose, but in the case of prints, drawings,

and paintings, the difficulty is to attain satisfactory results without loss of brilliancy in the pigments and ink. Therefore to make the treatment effective with this material experience is of the utmost value. The common bleaching agents are sunlight, ultra-violet rays, ozone, hydrogen peroxide, chloramine T. ($\text{CH}_3 \cdot \text{C}_6\text{H}_4 \cdot \text{SO}_2 \text{Na} : \text{NCl}$), sodium hypochlorite, calcium chlorohypochlorite (known as bleaching powder) and potassium permanganate followed by sulphurous acid or oxalic acid. They are given here in the order of increasing bleaching power. Each of these have their own utility. Sodium hypochlorite, bleaching powder and potassium permanganate followed by sulphurous and oxalic acids are more drastic in action.

Sunlight, ultra-violet rays & ozone are the easiest methods of producing bleaching effect. Hydrogen peroxide is used in alcoholic or aqueous solutions according to necessity. The active agent in bleaching substances is the liberated oxygen which causes oxidation. In chloramine T, sodium hypochlorite and bleaching powder, it is the hypochlorous acid formed or present, which liberates oxygen to cause bleaching. Chloramine T is a solid powder, and is used as a 2% solution in water. The solution is made just before use as it decomposes on standing. The greatest advantage with this reagent is that it is milder in action and its bleaching properties are soon lost, and it does not leave any corrosive material behind. Washing with water is thus reduced and can be dispensed with. It is therefore suitable for the removal

of stains from water colour drawings and paintings.

Sodium hypochlorite and calcium hypochlorite solutions are alkaline in behaviour and their solutions as such tend to soften the paper. This tendency is counter-balanced by making use of hydrochloric acid with the reagents. Sodium hypochlorite is available as an aqueous solution, and calcium hypochlorite is a solid. 1% solution of the bleaching agents is generally used for bleaching purposes but the strength is increased in the case of more resistant spots. Alternate treatment with the bleaching solution and 1% hydrochloric acid has a powerful bleaching effect—discharging the colour imparted by dirt, mildew stains, flymarks, ink stains, etc. Washing with water is carried out until the last tricklings do not give test with silver nitrate solution. The process requires a long washing treatment for elimination of acid. The most drastic bleaching effect is produced by treating the stain with .5% potassium permanganate solution followed by an aqueous solution of sulphur-di-oxide or 5% oxalic acid solution. The brown stain produced with potassium permanganate is immediately discharged. This method is to be used only in case of emergency and is regarded as the last resort. Immediate and thorough washing is absolutely necessary otherwise the paper is destroyed.

Stains of Organic nature :

Deposits and stains of an organic nature (grease, oil, resin, tar and smoke) require organic solvents

for their removal. The simplest way of removing oil or grease is to apply a small pad of cotton wool damped in petrol to the stain when most of it is removed. When only a little remains, soft brushing of the stained area is done under petrol. The best way is to place the specimen face downwards in the liquid and the back brushed from time to time. If the stain is resistant to petrol, acetone is tried, since animal and vegetable oils are more easily soluble in this. Toluene, xylene, chloroform and ethylenedi-chloride are also found to give satisfactory results for the removal of these stains. In case it is not possible or desirable to dip the whole specimen into the solvent, cotton wool pad is used to apply it, but it is then necessary to prevent the stain from spreading, by "ringing" it, that is, by moistening the material round the spot with water, or with a mixture of equal parts of alcohol and water. Usual precautions against naked light or fire are taken when the organic solvents are being used for this purpose.

There are many cases when all these solvents fail to remove the stains completely, then aqueous solution of pyridine is used. This removes, asphaltic stains readily and oxidised oil partially. It has an offensive smell and needs thorough washing with water on both sides of the specimen. Also care is to be taken to prevent action on the medium of ink in painted and printed material. If it is a water colour painting, then aqueous pyridine is used only after the pigments have been well fixed so that they do not run out on wetting.

The washed specimen is then pressed between sheets of blotting paper and glass to facilitate drying and leave the specimen flat. When oil or grease stains are of long standing, it is extremely difficult to deal with them.

Flymarks :—

Flymarks are generally on the surface, but when the paper is soft and porous, the blemish is found to have penetrated more deeply and then more drastic treatment for their removal is called for. Touching the marks with a brush dipped in alcoholic solution of hydrogen-per-oxide makes the deposits loose and the spots dull. Further working on the spots with a fine brush and hydrogen-per-oxide removes the stains if they are on the surface only, but if deeply penetrated then a bath or immersion of the specimen in aqueous hydrogen-per-oxide is necessary. Flymarks generally come off by this treatment but if they persist chloramine T or bleaching powder solutions are tried. When it is desired to confine to the use of non-aqueous solution, an ethereal hydrogen-per oxide solution is used.

Ink Stains :—

As has been said before, inks are of different nature, and therefore different methods are adopted for removing the stains caused by them. Stains of Indian and Chinese inks can be removed with warm water and gentle brushing when fresh, but when they get old and are of the iron gall ink, the best way is to treat

them first with 2% chloramine T solution or 1% bleaching powder solution and then if they persist after washing, 5% solution of potassium-bin-oxalate or 5% citric or 10% tartaric acid is painted over the areas. Excess of these reagents is removed by changes of wet blotting paper. Stains of ink containing aniline dyes are removed with hydrogen-per-oxide. Original ink writing, which is desired not to be affected by the reagents during the course of cleaning, should be preserved before starting the treatment.

Mildew and Foxmarks :—

Sunlight treatment or sterilization with thymol may improve the appearance of the print but it may be insufficient to remove all discolouration and marks which may persist if the specimen are deeply infected. The marks can be removed with hot water if very light, otherwise they have to be bleached for complete eradication of stains with the care usually required for porous and soft paper. The bleaching solution is washed off with water.

Tea and Coffee Stains :—

These stains are removed by wetting the areas and applying a solution of potassium perborate on the stain and exposing to sunlight for about an hour. If the action seems to be harmful, the spots are washed off. Ethereal hydrogen peroxide is also useful after perborate treatment.

Washing for removal of salts, water marks and acidity :—

Salt incrustations mixed with dust particles are found forming aggregates on paper when their concentration is large. Material soiled for long in debris gets contaminated with salts, which not only produce ugly spots, but cause deterioration also on account of its hygroscopic nature. The removal of these salts is therefore necessary from the point of view of preservation. Washing with plain water until the salts get removed is quite enough. Here also if the specimen are water-colour paintings or inked material, the pigments are to be fixed with .5% methyl-methacrylate or 5% vinyl acetate solution, before washing treatment is carried.

Dirty water marks are most common in paper and a satisfactory method of removing them is to wash them with plain water and if necessary with lissapol solution (an I.C.I. product) or 1-2% pyridine solution followed by washing with water. Paper, under humid conditions, gets contaminated with acids by fungal attack. Alum and bleaching powder used during the course of paper manufacture also cause acidity with lapse of time. Some of the pigments in water colour paintings also get decomposed and liberate acid. Typical example of this is the decomposition of verdigris—a compound containing copper acetate which on decomposition liberates acetic acid, and the green pigment first becomes brown, then black and finally the pigmented areas get charred and fall off. Rancidity due to contamination with greasy

matter also imparts acidity. Such affected specimen have to be washed with water, but dilute ammonia solution and lime water can also be used to neutralize the acid.

Removing Creases, Mounting and Drying

There is hardly any antique paper specimen of painting, drawing and manuscript which after chemical treatment can be left as such without removing its creases and reinforcing it for preservation and presentation for exhibition. We have already seen that in most cases chemical treatment leaves the specimen in a damp condition, but if not, then damp it thoroughly on sheets of Nepalese paper a little larger than the object under treatment. The Nepalese paper in turn is laid over a sheet of glass about 2" bigger in size. The crease will have a tendency to fall back to the original condition, if not, flatten it out with a spatula and adjust the loose and fragile pieces in position. Drain off water by placing another sheet of Nepalese paper over it and passing over a wide brush lightly straight from the top to the bottom, so that the excess water gets out. Put a wet sheet of Nepalese paper on the specimen and brush it over with a little pressure so that there are no air bubbles in between. With the help of wooden batons or strips, the whole unit consisting of two layers of Nepalese paper and the specimen in between is lifted up and placed upside down in such a way that the face is downwards. The coating of Nepalese paper on the back of the specimen is then removed slowly

from one corner. If it has a tendency to drag the specimen with it, then put more water over it.

The back of the specimen is thus available to receive paste for mounting on Japanese or Nepalese tissue paper backing which should be larger in size than the specimen such that sufficient margin is left out on all the four sides. The excess water, if any, is drained out after adjusting fragments and loose pieces in proper position. The paste used should be uniform in thickness, with no aggregates here and there. The mounted specimen is beaten uniformly with a stencil brush to ensure thorough adhesion and then turned upside down and placed on the table with the help of wooden strips as before. A sufficiently damp brush is passed over the specimen to make it spread flat on the table and the overlaid Nepalese paper removed from one corner. Final adjustment here and there, if necessary, is made at this stage. The edges and the portions appearing loose are again beaten with stencil brush after keeping a Nepalese tissue paper between the brush and the specimen. Strips of paper are then pasted to fix the mount on the table. The specimen is allowed to dry slowly and uniformly. It can be regulated by covering it loosely with tissue paper sheets. As drying proceeds the pasted strips stretch the backing with the specimen uniformly on all sides. In about 24 hours drying is complete. The stretched unit is then cut with a mount cutter leaving suitable margin all round. The mounted object can then go on card boards.

PART—II

I The cleaning and preservation of metals

Composition :—

Metals commonly used for antiquities are copper, silver, lead, iron, gold, pewter (tin and lead alloy) electrum (gold and silver alloy) bronze, brass, billon (?) (tin and silver alloy or silver and copper alloy) and base silver. Bronze is a composition of copper and tin and brass that of copper and zinc. There are certain impurities such as arsenic, antimony, lead, iron, nickel, sulphur and phosphorus which are inherent in the parent metals. The additions of these metals to copper form harder alloys melting at lower temperatures than copper—thus facilitating casting. There are different qualities of bronze and brass depending on the percentage composition of its metallic ingredients and having specified utility. Base silver coins are made of alloys of silver and copper.

Incrustation :—

Agents responsible for corroding metals are present in air and ground both, the principal agencies being carbon-di-oxide, water-soluble carbonates, chlorides (NaCl etc.) and sulphur compounds (H_2S and SO_2). Incrustation forms as a result of corrosion of the constituents of the alloy. The process of corrosion

is complex and hence incrustation is also of a complex composition. The bronzes attain a kind of patina or a tarnish of oxides of copper and tin during the course of time. Due to handling, greasy coating is also formed over the surface. This patina is continuous over the surface and is firmly adherent. The patina or tarnish is a protection for bronze, but it is not a complete protection. It only delays corrosion.

Water, carrying air, carbonic acid and various destructive salts penetrates the patina through minute fractures by capillary action and osmosis. These salts attack the bronze and some of the products of corrosion dissolve in the water and are removed from the bronze. Others are insoluble and remain where they are formed as a brittle and sometimes incoherent mass of oxide of tin mixed with oxides, carbonate and basic chlorides of copper. Silicates, phosphates, sulphides and basic sulphates have been noticed among the compounds formed but other salts may also be present.

Some of the copper removed from the bronze in solution redeposits as oxide, carbonates, or in other oxidized form immediately outside the bronze. These newly formed minerals cement loose soil and any other particles, that may be near, to a firm mass or accretion. Where there is no soil present, the accretion is composed wholly of copper minerals and there is no visible difference between the outside and inside of

the mass. In such a case the accretion is firmly joined to the film of patina and cannot be separated from it mechanically nor can it be eaten away by acid without destroying the specimen. When the interior of the bronze retains its metallic appearance and there are 'boils' on the outer surface of the crust, there will be a pit in the metal under the boil which may be so deep that, if the specimen is thin and slender, it may get separated into two parts.

Cementing materials other than copper compounds may be present in the crust. Those commonly found are calcite, chalcedony and limonite. They are derived from outside sources and are never present in quantities sufficient to provide a firm bond after the copper minerals have been disintegrated. The part next to the metal consists of oxides and that on the outside surface of basic metallic salts, which approximate in composition to the naturally occurring copper minerals. Sometimes a thin intermediate layer of copper oxychloride lies beneath the outside surface, and if this is exposed by a knock or scratch, active decay breaksout sooner or later, due to electrochemical action. Chlorine is liberated and this attacks both metal and patina vigorously giving rise to light green powdery spots.

The alterations proceed until there is no metal left except in oxidized form. During corrosion the metal first gets pitted, then becomes thinner and takes the form of a metal core surrounded by a mixture of

the mineral products of corrosion. This action may continue until all the metal is attacked. The mineral mixture may be within the structure or it may be laminated.

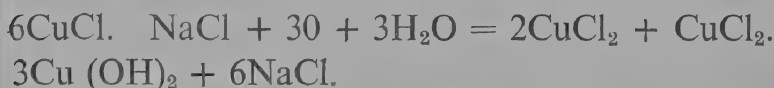
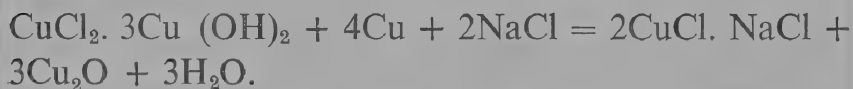
Difference of environments of the buried bronzes, specially with respect to circulation of air and water and the presence of corrosive salts in the surrounding soil account for the great difference in the state of preservation observed. Bronzes which have undergone advanced corrosion have irregular crust and are warped and swollen and consequently distorted in shape, resulting in complete obliteration of the original features. There may be deep longitudinal cracks gaping at the surface. The whole process causing such disruption in the internal structure of the alloy is a very complex one, and is partly explained, as follows :—

When a bronze which has undergone primary corrosion has a thick crust all over gets wet, the interior is saturated with water, which lies stagnant. This water, owing to its dissolved impurities, exerts a solvent action upon the cupriferos minerals and holds in solution a small quantity of copper salts, a quantity which is enough when such semi-soluble minerals as atacamite are present. During the dry period the enveloping soil dries first, the crusted surface next and the interior last. As the crusted surface dries, water is drawn from the interior by capillary action, evaporates from the surface and

leaves its dissolved compounds there as an addition to the crust. When the newly formed minerals are precipitated not on the actual surface but in the pores of the crust, the object gets distorted and cracked. Later, surface leaching may remove some of the substance of the crust which thereby gets shrunken and further distorted. This shrinkage causes the formation of the deep longitudinal cracks which are sometimes present.

Let us follow up the chemical changes taking place during the corrosion of a copper object through the agency of salt water charged with air and carbon-di-oxide, which are ordinarily present in the soil and atmosphere.

The simultaneous action of water, oxygen, carbon-di-oxide of the air and sodium chloride upon copper furnishes copper-oxy-chloride called atacamite. The equation representing the reaction is $4\text{Cu} + 2\text{O}_2 + \text{CO}_2 + 2\text{NaCl} + 3\text{H}_2\text{O} = \text{CuCl}_2 \cdot 3\text{Cu}(\text{OH})_2 + \text{Na}_2\text{CO}_3$. The thus produced atacamite undergoes further reactions with copper in the presence of sodium chloride and forms cuprous oxide and a double salt which is oxidised by air.



The cupric chloride, so formed in contact with air, attacks more copper to form cuprous oxide or may be converted into oxychloride.



Thus the cycle constantly recurs under the influence of moist air.

Patina :—

Some patina are free from chlorides and are probably formed without contact with soluble chlorides. They are comparatively stable and do not change under normal conditions and are called noble patina. Others principally those containing chlorides are unstable and are liable to spread and deepen and are called malignant patina. Malachite $\{ \text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \}$, azurite $\{ 2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \}$ with admixture of stannic oxide (SnO_2), ferric oxide (Fe_2O_3), and other oxides, cuprite (Cu_2O) and tenorite (CuO) are examples of noble patina formations; while atacamite $\text{CuCl}_2 \cdot 3\text{Cu}(\text{OH})_2$ is an example of malignant patina formation or bronze disease. Malignant patina has no relation to ordinary decay. During the course of this decay, the disease renews itself as shown by the above equation and therefore even the most minute quantity is theoretically capable of destroying the largest bronze.

The successive formations of incrustation on copper objects, in the presence of salty water and oxygen, are first a cuprous chloride (nantokite), then cuprous oxide (cuprite) and outermost basic cupric chloride-atacamite.

Treatment Methods :—

Two methods are adopted for chemical treatment of antiquities from the point of view of preservation.

(1) Chemical methods, (2) Reduction methods
 (a) carried by making use of zinc and caustic soda or acid-technically called the electro-chemical method,
 (b) by electrolytic method in which use is made of electric current.

Chemical Methods :—

These consist in making use of chemicals which dissolve the surface accretions and incrustations, reveal the artistic details of the object and eliminate all the injurious salts which cause the deterioration of the specimen. The choice of the chemicals depends upon the nature of the incrustation, its thickness and the extent to which the metals or the alloy and its constituents have undergone corrosion. As a matter of safety, start is made with the weakest chemical and then progressively drastic chemicals are made use of. Manipulative skill and imagination are essential to attain desired results. Experience is the only guide as to when to leave well alone, when not to undertake restoration and when to stop cleaning by chemicals.

Copper and its Alloys.

1. If the objects have superfluous soluble salts (sodium chloride etc.) on the surface or there is rancidity, simple washing with water (cold or hot) till the washings get free of salt and acid is quite enough. The presence of chloride salts is tested with 1% silver nitrate solution and acid with a litmus paper.

2. Harder thin copper incrustation is rendered loose with a dilute solution of sodium-sesqui-carbo-

mate. This method is useful for thin antiquities especially gilded ones.

3. If there is calcareous deposit, it is removed with sodium-meta-phosphate solution.

4. When antiquities are fragile and cannot stand more drastic treatment, but have diseased areas in the incrustation, 10% caustic soda treatment is given. The insoluble cuprous chloride is broken into soluble cupric chloride which goes into solution.

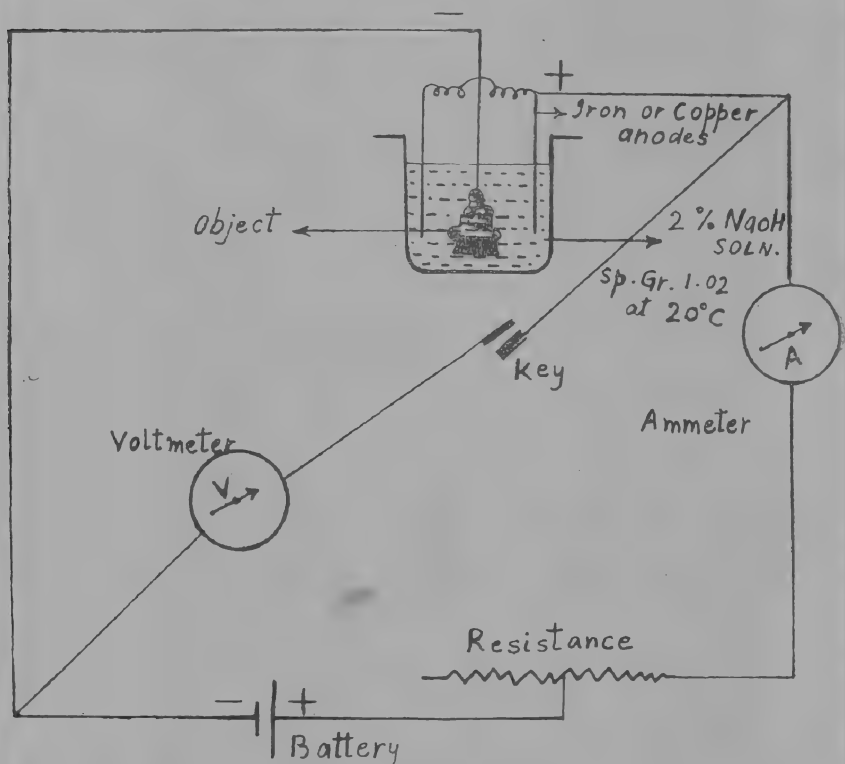
5. If there is superficial patchy oxide coating, it can be removed with dilute 5-10% ammonium hydroxide solution or 10% sulphuric acid Solution.

6. Objects with fairly hard and thick incrustation are treated with a 10% alkaline tartrate solution made by mixing 1 part of tartaric acid and caustic soda each to 10 parts of water.

2. *Reduction Method*

7. (a) Where there is enough metallic core and the incrustation is hard and thick, the objects are reduced with zinc and 10% caustic soda Solution or 5% sulphuric acid Solution. Caustic soda reduction takes about 12 hours but acid reduction can be completed in a comparatively shorter period. The slower the process the better is the result obtained. The active agent in the process is the hydrogen, which is evolved by the action of alkali and acid on zinc. Strong action, which results in excessive gassing is avoided, as in that case reduction is not uniform. This method is called electro-chemical method. (b) electrolytic

reduction is also carried out for the chemical cleaning of the objects. Here the hydrogen evolved at the cathode from a 2% solution of caustic soda brings about the reduction. The following details of the apparatus are given :—



In electrolytic reduction the lower the strength of the current the better is the result. Some times the crust resistance at the point of contact of the copper wire is so high that an appreciable current will not pass through the cell at first, but as the solution slowly penetrates the crust, reduction starts smoothly. The



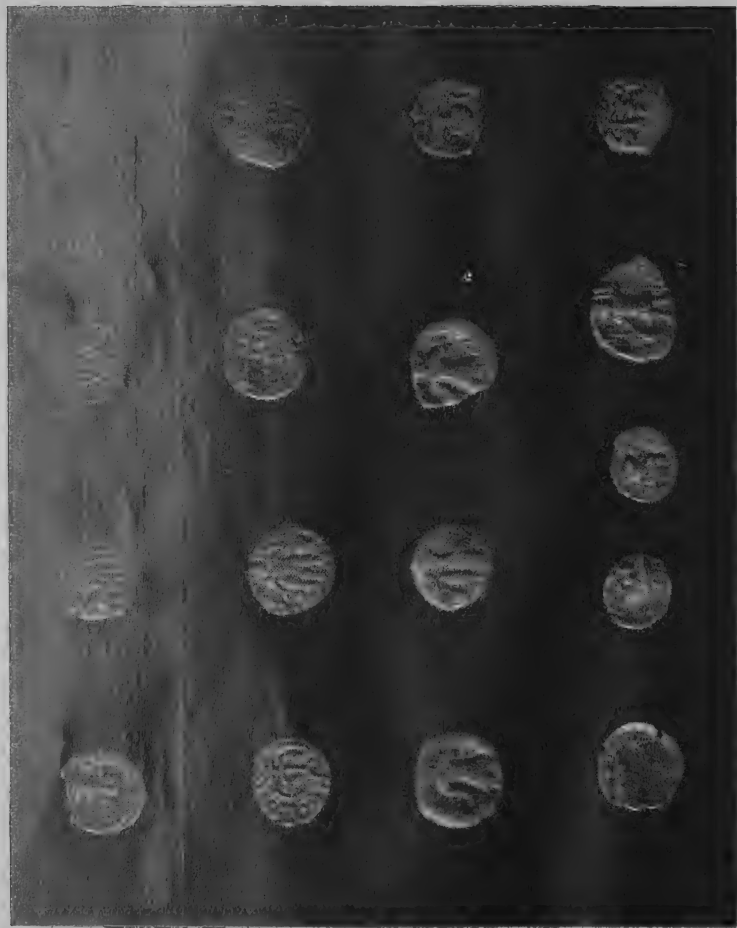
No. 15 Bronze figure from Nagda excavations.
Before chemical cleaning and preservation.



No. 16 Bronze figure from Nagda excavations.
After chemical cleaning and preservation.



No. 17 Hoard of Kushan coins from Rupar.
Before chemical cleaning.



No. 18 Hoard of Kushan coins from Rupar.

After chemical cleaning and preservation.

use of too strong an electrolyte and too high a current density is avoided.

8. There are cases where the diseased spots are only isolated patches and it is not desirable to treat the whole object, in such cases the isolated spots only are treated by making use of chemicals or paper pulp saturated with them and then when the treatment is complete washing the object with repeated changes of wet paper pulp. Electro-chemical reduction of the diseased spots is also recommended.

9. After subjecting the objects to chemical or reduction methods it is always necessary to remove the loose accretions from the surface by mechanical means.

Photographs 15 & 16 show the condition of a bronze leopard. The details of the animal were completely covered by the mineralized copper compounds. There were only two original wheels. (one for the front and one for the back). Photograph 16 shows the restored condition. Photograph 17 shows the condition of a Kushan coin hoard which was found stuck up together as a lump during excavations at Rupar. The decipherment of these coins was made possible only after chemical treatment and preservation as will be clear from photograph 18.

Silver and its Alloys

The usual incrustations on silver are silver chloride and silver sulphide. When it is an alloy of silver and copper, the object is covered with green copper in-

crustation. Silver chloride is removed with 5% ammonia solution and silver sulphide with a dilute solution of potassium cyanide. An alloy of silver and copper is treated alternately with formic acid and ammonia solutions till all green incrustation is dissolved out. 3% Citric acid solution is also found to give satisfactory results.

Reduction method consists in reducing the object with zinc and caustic soda or acetic acid solution.

Iron

Iron incrustation consists of the different oxides of iron and in the presence of soluble chlorides, basic chloride of iron is also present. Here also when there is very little metallic core, the object is treated with hot 5-10% caustic soda solution for a prolonged period say about three weeks and changing the used caustic soda solution after every week. Reduction method is adopted in cases where there is sufficient metallic core, but it is done with zinc and caustic soda only. Iron antiquities generally are incrustated with calcareous deposit which is found cemented with iron oxides. This is loosened by dipping the object in dilute nitric acid. For cleaning tiny and less corroded objects, potassium-bioxalate solution is used.

The incrustation on iron is generally so thick and laminated that mechanical treatment becomes necessary—even chipping of the cemented material is unavoidable.



No. 19 Iron arm plate.
Before treatment.



No. 20 Iron arm plate.

After cleaning and preservation.

Iron arm plate shown in photograph 19 was found covered with iron oxide only and hence preservation of this object was not very complicated. However chemical cleaning and preservation brought out the details of the inlay work very well as will be seen from photograph 20.

Tin and Pewter

Pure tin objects are rarely met with. Calcium carbonate concretions from tin objects are removed by treatment with dilute sulphuric acid followed by thorough washing. Pewter is an alloy of tin and lead and if objects of this alloy are badly corroded they are reduced with zinc and caustic soda solution as usual.

Lead and its Alloys

Incrustations on lead objects are white lead-basic-carbonate, oxides and chlorides. Chemical treatment, therefore, calls for the removal of this surface covering material. For dissolving out the basic carbonate, dilute acetic acid is the safest; though concentrated caustic soda and caustic potash are also frequently used. As in copper, iron and silver, reduction method is applied to lead objects also provided the metallic core is sufficient. Lead objects are very susceptible to the action of even weak acids and alkalies, and as such it is absolutely necessary to remove all traces of these chemicals finally.

Gold and its Alloys

Gold, if pure, is found in uncorroded condition, but if it is mixed with silver and copper, then corrosion products of these metals are found covering the objects. These incrustations are removed as already described before.

Preservation

After the metallic objects have been cleaned, it is absolutely necessary to see that all the chemicals used have been completely washed out from the antiquities, because any trace left inside the core will start attacking the metal and diseased spots will grow progressively. The object is then dried for about 4 hrs, at a temperature not exceeding 80°C. and then preserved with surface coatings such as vinyl acetate or methyl-methacrylate solutions. In case the object is porous, impregnation of the preservative is done under vacuum, so that it gets well saturated with the preservative. Bakelite solution is used as a preservative for iron.

Restoration

Many times it is necessary to do restoration of the antiquity in order to give it proper strength and shape. After the fragments have been pieced up together, the missing gaps have to be restored to add strength to the fragile and fragmentary pieces. Restoration, as a matter of fact, should be restricted to the bare minimum necessity.

Even after preservation and restoration there are such antiquities which have to be encased in suitable small transparent cases so that one does not handle the antiquity as such, but holds the case only.

II The cleaning and preservation of siliceous materials

Causes of deterioration :—

Siliceous materials are stone, pottery, terracotta, (baked or unbaked) stucco, brick mouldings etc. The chief causes of disintegration of this material is the presence of deliquescent salts which they absorb from the soil, and the lichen and moss affection which they develop due to excessive moisture and prolonged humidified conditions. The nature of the salty material absorbed depends on the locality, but it is generally a mixture of soluble chlorides, nitrates and sulphates some of which are hygroscopic. The alternate processes of hydration and dehydration of these salts bring about contraction and expansion inside the matrix of the material, and cause stress and strain-thus resulting ultimately in the destruction of the object. There is large scale flaking of the surface and the material is reduced to powder.

Moss and lichen are fungal growths and they develop on the stone surface due to excessive damp. It is difficult to eradicate this menace, when once it sets on. The stone surface becomes the seat of infection which spreads further over the surface and deep into

it-depending on the compactness of the stone. Moss and lichen have the property of absorbing moisture from atmosphere and consequently keep the stone surface permanently damp. The result is that there is patchy ugly look on the stone surface and under the patch the stone surface gets pitted.

Calcareous deposits are more or less a common ingredient of the accretions on this material. In standing monuments, the absorption of deleterious salts is from the polluted atmosphere of industrial towns or winds carrying sea salts.

Often the stones bear stains, which look ugly and hence, they need removal. The chemicals used for their removal are the same for each kind of stone, excepting that acids are not to be used in the case of marble and lime stone. Oily and greasy marks become seats for accumulation of dust and other extraneous matter which not only cause disfigurement of the surface, but produce pitting also.

The stone materials that we come across are hard stone, granite, marble, lime stone, alabaster, sand stone etc. Hard stones do not generally absorb any salt, but can have accretions just on the surface which are easily removed with plain water or dilute acid solution, if it is of calcareous nature. Granite, although naturally a hard rock, often suffers surface disintegration. Marble and lime-stone belong to one category in so far as they are both calcium carbonate

—the difference being in their natural formation only. Alabaster is commonly calcium sulphate and is very soft. Sand stone has different varieties ranging from coarse grained to fine grained.

Treatment :—

For the removal of soluble salts, two methods are adopted (1) steeping in water, (2) treatment with wet paper pulp. Both these methods are quite effective but the later is slow and more expensive. In standing monuments, where the stone work cannot be steeped in water, paper pulp treatment is the only solution for eliminating salts. These methods are not applicable to unbaked clay and stucco objects and materials painted with water soluble medium. Unbaked clay and stucco objects cannot be wetted and elimination of salts from them is impossible. Painted stone work can be subjected to elimination of salts treatment after the painted surface has been coated with a fixative solution of vinyl acetate or methyl-methacrylate. Soluble salts from alabaster and gypsum are removed by steeping them in water saturated with calcium sulphate.

Moss and lichen are eradicated by brushing them off with a dilute solution of ammonia followed by the application of a dilute solution of zinc-silico—fluoride or sodium-pentachloro-phenate which eradicates such aquatic growths.

For the removal of calcareous matter (CaCO_3 and CaSO_4) use can be made of dilute hydrochloric acid

followed by thorough washing. This holds good in the case of hard stone, granite, sand stone, etc., but not for marble, lime stone and alabaster which are readily attacked with acid and get pitted even in very dilute concentrations. From such materials, the accretions can be removed only by scrubbing with a sharp knife.

Stains of organic nature are removed by making use of organic solvents such as petrol, benzene, alcohol, ammonia, pyridine and chloramine T etc.

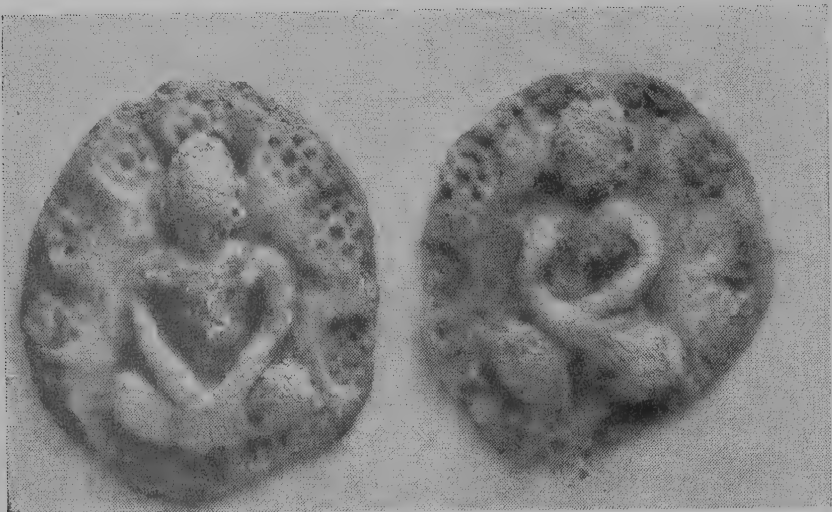
Preservation and Consolidation :—

When treatment of the material is complete, it is to be coated with a preservative which, besides providing a surface layer, penetrates into the matrix. The preservative coating is applied when the stone or pottery has dried thoroughly. In cases, where the specimen is very porous, impregnation under vacuum is found necessary. In the case of highly salt saturated stucco or unburnt clay object, even after vacuum impregnation it is necessary to keep the objects in dry atmosphere. The preservative coatings used are solutions of vinyl acetate and methyl-methacrylate. For preservation of unbaked pottery, it is sometimes desirable to bake them at about 600°C. for a prolonged period of about 6 hours. Baking renders the object hard and then elimination of soluble salts is facilitated.

Photograph 21 represents two unbaked clay plaques of seated Buddhas from Central Asia. This was highly



No. 21 Unbaked clay objects from Central Asia.
Before preservation.



No. 22 Unbaked clay objects from Central Asia.
After preservation.

saturated with salts which were responsible for bringing disintegration of the stucco. The after preservation condition of this material is shown in photograph No. 22.

Joining of the stone work is done with Meyer's cement, which consists of magnesium oxide and magnesium chloride solution mixed to form a paste. When the pieces to be joined are heavy, dowels are necessary to be inserted. Pottery is joined with shellac and its small fragments with thick vinyl acetate or methylmethacrylate solution. Repairs to pottery is done with plaster of Paris tinted to match the original colour.

Glass, Faience, Glaze and Enamel Objects

Composition :—

Glass, glaze and enamel form one group of materials in so far as their modes of formation and compositions are almost the same. They are highly siliceous materials. Variations in a few of their physical properties such as colour, transparency, lustre etc. are due to the presence of comparatively small quantities of certain colouring ingredients and the temperature of firing. Glass is manufactured by melting together sand, alkaline oxides such as soda, potash, lime and leadoxide which give rise to the solution of mixed silicates varying widely in composition. Common types of glass are soda lime, potash lime and lead glasses. The common colouring ingredients in glass

and glazes are oxides of iron, copper, tin, manganese, cobalt, lead etc.

Deterioration :—

Glass is resistant to almost all chemical reagents under normal conditions, but prolonged exposure to water, specially in presence of dilute acids and alkalis makes the surface roughened. Glasses containing large proportion of alkali are apt to decomposition at a quicker rate than others. Gradual leaching away of the alkaline silicates takes place during decomposition. Besides decomposition of the material, the colouring ingredients often undergo change.

The decomposition of ancient glass is due to the fact that such glass contains an excess of alkalies. It attracts moisture from the atmosphere containing carbon-di-oxide in solution. The result is a chemical decomposition accompanied by the formation of sodium carbonate and the separation of siliceous material.

Decomposed glass may have sweating and dimmed surface and may be opalescent, incrustated and pitted due to scaling off. These pitted spots, if continuously exposed to moisture, become seats for lichen infection which carries deterioration further,. In glazes, due to the liberation of surface silica film, the colour is masked. In faience, flaking of glaze, due to the crystallization of salts beneath, takes place. Enamels and polychrome glass suffer a loss and change of colour.

Treatment :—

In all these cases the alkaline exudations are neutralized with dilute hydrochloric acid solution followed by thorough washing. The accumulation of silica on the surface is either removed by making cautious use of 1% hydrochloric acid or mechanically scraping off the surface carefully.

In case of lichen affection, the surface is brushed with a dilute ammonia solution—the excess being neutralized with an acid. Potash glasses show incrustations of potassium carbonate which attract moisture and render the surface damp, such a glass in this condition is some times called as ‘Sweating Glass’. For preservation, this is treated with a 2% sulphuric acid solution and then washed free from acid.

For preservation, glasses and glazes are dried as usual at about 80°C and then coated, with preservative solutions such as Canada Balsam and enert synthetic resins. Joining of glass objects is done with thick solutions of vinyl acetate, methyl-metha-crylate and celluloid solutions. It is not desirable to use gelatinous compositions.

APPENDIX

Some Common Reagents, Solvents, Solutions and their uses

1. *Silver Nitrate* :—1 % solution in 5 % nitric acid—used for testing the presence of chlorides.
2. *Barium chloride* :—10 % solution—used for testing the presence of sulphates.
3. *Hydrochloric acid* :—5 parts of strong acid and 95 parts of water give a dilute solution and is to be used for the removal of calcareous incrustations.
4. *Thymol Solution* :—5 % solution in alcohol or rectified spirit—used for thymolising paper manuscripts and drawings against fungal and mould growth.
5. *Acidity and alkalinity* :—Blue litmus is turned red by acids and red turned blue by alkalies. 1 % phenolphthalene solution in rectified spirit gives red colour in alkaline solutions.
6. *Solvents (organic)* :—

Acetone :—Boiling point is 56°C. Miscible in all proportions with linseed, tung, polymerized oils, water and most other solvents. Dissolves cellulose derivatives, vinyl resins, natural soft resins and certain waxes. It can safely be used in well ventilated places, though its vapours are highly inflammable.

*Alcohol (Ethyl)—Rectified spirit :—*Absolute alcohol has boiling point 78°C . Strongly hygroscopic, miscible with a wide range of solvents including turpentine and benzene. Strong solvent for oil paints and certain lacquers.

*Ammonia Solution :—*Ammonia gas (NH_3) is very soluble in water. It is a mild alkali and as such can cut thin films of oil and grease. Concentrated ammonia water is about 28% NH_3 . The presence of the dissolved gas in the mixture of water with organic solvents acts rapidly on fatty or greasy materials and can be used occasionally with safety in their removal from surfaces of paintings.

*Amylacetate :—*Boiling point 148°C . Miscible with linseed oil, but mixes with water only very slightly. Good solvent for many resins.

*Benzene, toluene and xylene :—*These are aromatic organic solvents. Boiling points are 80°C ., 110°C . and 139°C . respectively. They are miscible with most organic solvents but practically not with water. Toluene and xylene are not so dangerously toxic as benzene.

*Benzine (Petroleum spirit) :—*It is different from Benzene and is a petroleum fraction below kerosene.

*Carbon-di-sulphide :—*Boiling point 46.3°C . Heavy volatile liquid with disagreeable odour. Mixes with most organic solvents, but only slightly with

water. Highly inflammable and forms explosive mixtures with air. The vapour ignites even with an electric lamp. Vapour strongly toxic. Good solvent for oils, fats, waxes, rubber and a number of resins.

Carbon-tetra-chloride :—Heavy liquid B. P. 77°C . Non-flammable and therefore has a unique place among organic solvents and is miscible with most of them. Oils and soft resins dissolve to certain extent.

It is mixed with other solvents to cut down the fire hazard. At moderate temperatures it is stable to water and light but at elevated temperatures it reacts with water to form hydrochloric acid.

Chloroform :—Boiling point 61°C . Miscible with most of the organic solvents and with vegetable and mineral oils.

Ether :—Boiling point 34.5°C . Completely miscible with alcohol and with most organic solvents, but with water only to the extent of 7.42% at 20°C . used either alone or in mixtures for the removal of resin and wax. Solvent action is very wide on oils, resins, fats and waxes. Because it evaporates rapidly it has little use as a commercial solvent for lacquer.

Paint Removers :—Most of them are mixtures of organic solvents. Ammonia also is a common ingredient and with it are acetone, methyl alcohol and benzene. To reduce flammability, chlorinated hydro-

carbon like trichlorethylene are added. Many such mixtures are patented. Speed and completion of solution in a paint remover, as in any single solvent are dependent upon various factors in the paint and on the combination of materials used in it. Dried oil films get dissolved only in strong alkalies.

Turpentine :—Boiling range 150° - 180°C . Immiscible with water, but mixes in most proportions with nearly all organic solvents. All vegetable and mineral oils in a fluid state are miscible with turpentine and it dissolves most resins, except those of fossil origin and most waxes.

Naphtha :—Boiling range 100° - 160°C . It is a common turpentine substitute.

7. *Insecticides and Fungicides* :—From prehistoric times insects and fungi have been man's problem, and the extent of the damage caused by them both to animal and plant kingdom in their living or dead condition, and the means adopted for their control and eradication gradually developed to the present stage with the changes in his living conditions and environments fitted to meet his requirements in different periods. Methods of pest control are mechanical, biological, environmental and chemical. The first three methods are extremely useful, but they are sometimes neither possible nor practical and hence chemical control methods are employed. Chemicals for insect control are (1) insecticides consisting of

stomach poisons, contact poisons, fumigants, (2) attractants and (3) repellants. Similarly chemicals for fungus control are fungicides consisting of eradicants and protectives. The distinction between stomach, contact poisons, protective and eradicant fungicide is difficult to make. Many materials have overlapping properties and hence it is not always possible to make definite classification.

Fumigants :—If it is desired to use carbon-di-sulphide singly, 1 ounce of it per cubic foot of space is required to be kept in the air tight container and the articles are spread inside properly. The container is closed tightly with strips of paper pasted round the lid. In two or three days time the fumigant disappears. The lid is opened after a week and a fresh supply of the liquid added. After the lapse of the second week sterilization is complete so far as is possible at the time. Eggs of the insects may have survived and refumigation may be necessary in due course, when these hatch out. As carbon-di-sulphide forms an explosive mixture which can explode even by a lighted cigarette, a mixture of four parts by volume of carbon-tetra-chloride and one part of carbon-di-sulphide is used to avoid this explosion risk.

8. *Preservative Materials* :—

The various preservative materials used are wax singly or in mixtures with turpentine and toluene, oil and spirit varnishes, cellulose and vinyl acetates.

and methyl-metha-crylate solutions. The solutions are in organic solvents which volatilise away leaving behind the preservatives on the specimen. For better penetration, dilute solutions with lower viscosities are used to render effective preservation. 3-5% vinyl acetate in (50 : 50) toluene and rectified spirit and -5% methyl-metha-crylate in 75% toluene, 24% methyl-alcohol with or without 1% di-butyl-phthalate are considered to be better preservatives.

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IX	3		vii-against introduction under Page.
4	12	render	renders.
10	16	beckground	background
24	2	or	on
31*	7	its	the
32*	1	red	reds
63*	1	electrolytic	Electrolytic
72*	1	This was	This material was
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50, 77.

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29, 56, 61, 63, 66, 67.

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7, 21.

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7, 21.



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